Non Linear Junction Detector Review and Tutorial

Back in the early 70's a method was developed to detect eavesdropping devices though the analysis of harmonic emissions caused by an illuminating signal when it is reflected off of a target. A few years later this method was used by the Superscout NLJD system (which was the first commercially available and patented NLJD).

Semiconductors contain multiple layers of silicon, a P-Type and an N-Type, the point where they meet is called a Non Linear Junction. This junction also appears in nature when dissimilar metals come in contact with one another (such as that used in the old crystal radio set). Also, the rust on a screw, the springs in a car, or the support structure in any piece of furniture may also contain non linear junctions (resulting from corrosion).

A Non Linear Junction Detector finds potential eavesdropping devices by flooding a suspect area or target with a spectrally pure microwave RF signal (usually around 888 or 915 MHz). Various frequencies are then monitored for a reflected harmonic signal.

The instrument typically has an antenna and a control unit. The antenna is mounted on an extendable pole, and really nothing more than a microwave waveguide which both emit and collects the signals (with a duplexer). The control unit is usually a multiple channel, highly sensitive radio receiver tuned to specific second, and third harmonic frequencies. While it is possible to measure the 4th, 5th, 6th, and other harmonics those above the third are only of limited TSCM value.

ORION NJE-4000 Non Linear Junction Detector

TSCM technicians are often portrayed in movies and marketing materials as someone slowly sweeping a wall with a complex device on a boom, carrying a control box over the shoulder, and a set of headphones over the ears (much like a metal detector). This portrayal actually shows the usage of a NLJD in action, and it has long since been accepted by the public as "how the job should look like."

A Non Linear Junction Detector may be used to identify:

Active or Live Bugs
Inactive Bugs
Turned On Bugs
Turned Off Bugs
Burned Out Bugs
Dead Bugs
Covert or Concealed Video Cameras
Microwave Transmitters
Remote Control or Remote Powered Bugs
Resonant Cavity Devices
Concealed Cellular, PCS, and GSM Telephones
Electronic Timers for Hidden Bombs
Wireless Microphones
Hidden Tape Recorders (even broken ones)
Covert Eavesdropping Devices
... or nothing at all ...

A Non Linear Junction Detector is nothing more than an instrument which detects harmonic anomalies, nothing more. Any positive indication must be verified with a metal detector, X-Ray examination, thermal viewer, and a physical inspection to confirm the actual presence or absence of an eavesdropping device. While the NLJD is not a "magic wand" it is much less destructive then a sledgehammer and a number 14 screen.

How to Properly Use a Non Linear Junction Detector

Before using a NLJD the area must first be subjected to a comprehensive "Non-Alerting" TSCM inspection. This must include a "Non-Alerting" check for any type of free space electromagnetic signals including any signals or voltages present on all conductor combinations (including telephone, AC, lighting, HVAC, IDS, and so on). The area must also be checked for thermal and IR anomalies before the usage of the NLJD (which marks the beginning of the "Alerting" stage of the TSCM service).

If you only have limited time in which to perform the TSCM Inspection then the time is best spent on other elements of the sweep such as the RF survey (and you should leave your NLJD out of the equation). However, when you have the luxury of time and your schedule permits it usage; the NLJD becomes an invaluable tool just like the portable X-Ray or thermal imager (but it is very time-consuming to use).

Proper operation involves slowly brushing or sweeping the antenna over every surface in the suspect area. The procedure is very slow and time consuming, typically involving 2-5 minutes per square yard of surface area. A small 15 * 15 foot office will typically require four hours to sweep with such an instrument. The TSCM specialist literally "paints" every surface in the area, including walls, floors, ceilings, furniture, and fixtures. If a circular polarized antenna is used the time require to sweep can be reduced by about 30%.

The area to be inspected will first be swept using a "quiet" mode of operation where the instrument is used to listen only and to observe the quieting effect which RF fields tend to create. During this period the audio output of the NLJD may be monitored with headphones to detect the sync "buzz" created by video transmitters, or the emissions from the bias oscillator in some tape records (if you get lucky).

The illuminating signal will then be activated and the NLJD used to scan the walls and surfaces from a distance of at least 6-8 feet outside of the area to be inspected. The purpose of this scan is to isolate and evaluate items creating false positives. Once these item are "cleared" they should be isolated from the area being inspected (to avoid further interference).

Once the area has been sterilized of all major "harmonic reflectors" the distance between the NLJD is reduced to 2-3 feet and repeated to further isolate and evaluate potential "hits".

Finally the distance is reduced to between two feet and actual contact with the item or area being inspected. The lowest possible signal levels are used first for the initial "contact sweeps" and the entire area checked again. The power is then increased slightly (no more the 25%) and the entire area re-swept. The power is again increased and the entire sequence repeated until full power is reached. If possible the power should be increased in as small a level as possible (10% is ideal, but 25% is practical) with multiple overlapping sweeps of the area using multiple directions.

The flat surfaces (such as walls) in the area should be swept at a rate of 3 seconds per square foot or less. Non flat surface (such as furniture) will of course be swept at a much slower rate. A "perfectly clean room" will take at least 30 minutes to check with a NLJD, with a typical small office (less then 200 square foot) taking 2-3 hours, and a medium sized office taking at least 3-4 hours. A larger executive office may easily take 6-8 hours or more often involve several days just for the NLJD

inspection. (On humorous note, the TSCM specialist will actually look like he is practicing Tai Chi with a painters pole). Properly sweeping a room takes as long as applying three coats of paint to all of the walls in a room (it takes time... lots of time, and is tedious).

Advanced NLJD Usage Methods

Since the use of a NLJD should be considered "highly alerting" the TSCM'er will be able to "thump and bump" possible metallic or corrosive targets to isolate them as false targets. Light switches, fluorescent lights, modern electronics, nails, paper clips, steel screw studs, furniture springs, and so on create the most false targets and will create a noisy and unpredictable response in the reflected signals.

Applying a small amount of physical vibration to the suspect area will disturb the crystalline structure of the corrosive or dissimilar junction and will usually cause a detectable shift in the NLJD reading. This physical vibration may be created by several commercial products including rubber mallets, orbital vibrators, low frequency ultrasonic vibrators, palm massagers, and so on. A false or corrosive hit will create a noisy signal which may be heard in the earphone, but a real threat may also cause such a crackle.

Each anomaly is then carefully documented and evaluated to determine exactly what caused the "hit" and a record of these should be maintained for future study.

Even when properly used Non Linear Junction Detectors are prone to false alarms, and may cause many hours to be expended only to find a paper clip which had been dropped into a potted plant, or two staples inside a book. On the other hand the NLJD may to used by the TSCM practitioner to develop a "sixth sense" about a area being inspected, and when combined with a portable X-ray, thermal imaging system, and borescope the instrument becomes invaluable for finding professionally installed eavesdropping devices.

Illuminating Signals and Harmonics

Transistors, diodes, integrated circuits, and other dissimilar or metallic junctions will usually cause a signal to be emitted at the second or third harmonic of the fundamental flooding frequency.

Fundamental or Illuminating Signal - Conductive or Metallic Surface
This is the flooding frequency, typically 888 Mhz or 915 MHz. Power levels range from 15 mW to 7.5 Watts, 3 W typical for government, below 1 W ERP for commercial. A reflection of this frequency may be monitored to allow the calibration of the instrument or to control output power levels.

Linear Response
A linear response will be caused when a NLJD is passed over a non metallic, non ferrous, or organic item. This material includes, potted plants, wood, paper, rubber, plastic, wool, fabric, or other item. Instead of reflecting the fundamental frequency, or generating a harmonic the signal is instead absorbed by the material. Most objects will respond in a linear fashion.

Fundamental Signal, 3rd, 5th, and other Odd Harmonic Reflections
(Conductive or Metallic Surfaces)
This harmonic will be reflected by any conductive or metallic surface within the area being inspected. Normally this harmonic is only useful for locating nails, screws, studs, conduit, and other normal structural components. This will include any metal to metal junctions of the same type of material such as electrical conduit, HVAC duct work, and metallic studs. This is considered a negative response and may be considered a non-linear symmetrical response.

2nd, 4th, 6th, and other Even Harmonic Reflections
(Dissimilar Metallic Junction and Non Linear Junctions)

Any type of metallic junction between multiple items of metal will cause a second harmonic to be generated. This signal may be created by solid state devices, diodes, transistors, or integrated circuits. However, this signal may also be caused by the presence of paper clips, rusty nails, sheetrock screws, steel studs, re-bar, upholstery springs, or any loosely touching metallic parts. This is considered a positive response, and will require further inspection involving a portable X-ray instrument, thermal imaging, borescopes, and other physical equipment. This may also be considered a non-linear assymetrical response. A noisy assymetrical response indicates the possibility of a corrosive target as opposed to a bugging device.

NLJD Power Outputs (ERP)

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15 - 100 mW	**Virtually Worthless**
100 - 500 mW	**Minimally Useful**
500 mW - 2 Watts	**Typical Range (5 mW - 2 W is ideal)**
2 - 5 watts	**Generally not used**
above 5 watts	**Too much power, may cause injuries**
above 300 watts	**Russian units (bad for your health, but helpful for warming your lunch)**

Power Level Issues

Non Linear Junction Detectors are available in a variety of power outputs ranging from the "civilian" version with an output below 25 mW, to the restricted Government version with a power output over 2 watts ERP. The Soviet and Chinese government actually use NLJD instruments which generate hundreds of watts of power, but often cost the TSCM specialist their vision (and other soft tissue damage) due to high levels of non-ionizing radiation. On an added note a NLJD should not be directed to any human or other living creature due to the potential of serious bodily harm. You can actually knock out a cardiac patients pacemaker from a distance with one, or cause serious soft tissue damage such as cornea injury, loss of hearing, kidney failure, and so on.

As the power output increases the greater the range of the unit, and the penetration into solid materials. However, as the power level increases, the sensitivity of the unit will decrease.

Normally a 2 Watt NLJD will detect an eavesdropping device through several inches of concrete, inside a wall, or buried deep inside a couch. The lower power units (50-100 mW) on the other hand will only detect eavesdropping devices inside a book, or devices only an inch or so away from the antenna (such as behind a few layers of sheetrock).

Non Linear Junction Detector transmit power is relatively meaningless. The sensitivity and bandwidth of the receiver is a far more important issue. Cheap units use high power to overcome poor receiver sensitivity and poor noise figures. In general the better units (more effective) are the lower powered ones.

Much like an X-ray the power level must be variable based on the density of the object being inspected. Of course the more power you generate the more "alerting" your activities become, and the higher the risk of personal injury (just like taking an X-Ray).

Generally a 1.5 Watt ERP unit with a variable output (adjustable down to around 5 mW ERP) works well, but if you use Digital Signal Processing or DSP in the unit to increase sensitivity the power levels can be drop to well below a Watt.

Frequency Issues

Fundamental Frequency	Second Harmonic	Third Harmonic	
320 MHz	**640 MHz**	**960 MHz**	
418 MHz	**836 MHz**	**1254 MHz**	
520 MHz	**1040 MHz**	**1560 MHz**	
888 MHz	**1776 MHz**	**2664 MHz**	- 2nd Most Common NLJD Frequency
915 MHz	**1830 MHz**	**2745 MHz**	- 1st Most Common NLJD Frequency
1140 MHz	**2280 MHz**	**3420 MHz**	

The 888 MHz products should be avoided as they tend to interfere with cellular telephone systems within the United States. On the other hand most professional eavesdroppers will monitor all popular NLJD channels to detect a TSCM sweep. For this reason it is advisable to utilize a non standard frequency, and to keep the power output as low as possible.

When a microwave sweep generator is synchronized and offset to a digital spectrum analyser the results are far superior to that of any NLJD (but much more expensive). For this reason NLJD's rapidly lost favor during the late 1980's, and have since been replaced with microwave sweep generators (if you don't mind dragging around an extra 60+ pounds of equipment). The technique of using a sweep generator as a NLJD signal is know a "Chirping".

A tunable NLJD works very well, but only after the spectrum has been checked with a spectrum analyzer. Also, the NLJD illumination signal may be pulsed to determine distance to the suspect junction and to reduce the power required (available in some NLJD systems). The pulse may also be created to appear like a legitimate communications signal (such as a POCSAG or CDPD data burst on an appropriate channel) to enhance operational security. Additionally, a pulsed signal may be coupled with a computer controlled receiver to radically increase the ability to detect potential threats.

NLJD Vulnerabilities and Weaknesses

Many modern eavesdropping devices utilize shielding and isolation circuits to hide the device from Non Linear Junction Detectors. Also, devices may contain special alarm circuits which will shutdown the device should a flooding frequency be detected or in some cases may even cause the device to self destruct with a small charge.

Perhaps the most valuable usage of a NLJD is the examination of organic, or quasi-organic objects such as potted plants, wooden desks, tables, books, and other things made of wood, fabric, composites, and non-metallic objects. The NLJD will also be valuable when examining wood paneling, wooden bookcases, paper, ceiling tiles, persian rugs, and so on. While a NLJD may be used with limited success on or near metallic surfaces such usage should be avoided as virtually every metallic junction will cause a false alert.

All weaknesses and misconceptions aside; the NLJD does have a place in every TSCM equipment inventory. When properly used during a sweep it will find eavesdropping devices that other instruments will miss. However; always remember that a NLJD is only one part of a complete set of TSCM equipment, and that it is only as good as the operator.

Popular Industry Models

Super Broom NLJD (A decent unit, popular in England)

SuperScout (The original NLJD, no longer available)

Hawk

Boomerang-4 (Older unit, but still available)

Locator (Popular with U.S. government sweep teams)

Diviner (Never really caught on)

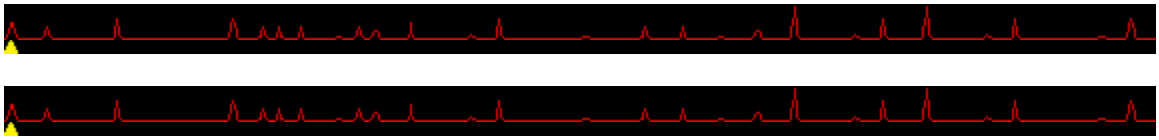
TRE-700

Mod 8, Mk 4 (British unit with sonic thumper)

Sounder III

Orion NJE-4000 (The most popular and most requested NLJD is the ORION or NJE-4000. The ORION was actually the first NLJD in 25 years that was not just another knock off of the SuperScout).

Spectrum Analyzers	Vector Signal Analysers	Demodulation	Time Domain Reflectometers
Antenna	Oscilloscopes	Multimeters	Craft Instruments	TSCM Specific Instruments
Non Linear Junction Detectors	Acoustic	Physical Search	Photographic and Imaging
Auxillary	Ancillary	Video	Vehicles



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