



NEW Nardalert S3 Mainframe shown with interchangeable sensor.

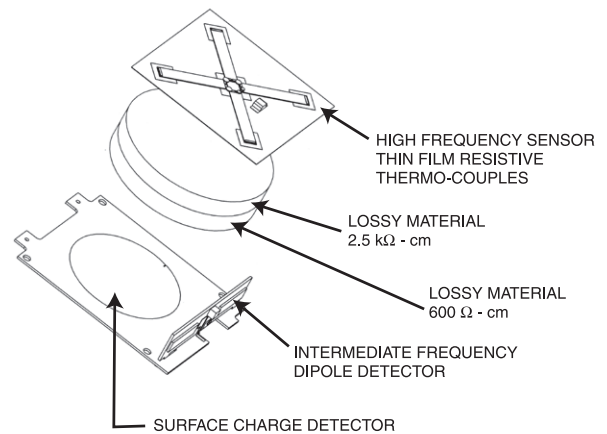
### Ultra-Wideband

## Electromagnetic Radiation Monitor

*This paper was originally presented by Edward Aslan at the Bioelectromagnetic Society (BEMS) annual meeting in St. Paul, MN, June 2001. It describes the development of the Nardalert XT personal monitor. This sensor has been since updated for use in the Nardalert S3.*

### Abstract

Personal radiation monitors of the prior art are effective only within a kilohertz, megahertz, or a gigahertz range, a pre-determined high frequency range, or a predetermined low frequency range. Attempts to fabricate radiation monitors with a capability of detecting electromagnetic radiation in two or more of these ranges have met with great difficulty in the past. This problem is primarily due to interference between various high and low frequency components of the monitor that detect different bands of frequency within the desired bandwidth. This problem has been solved by designing a monitor that includes a low frequency surface charge sensor, a planar array of thin film thermocouples comprising the high frequency sensor, and a lossy material sandwiched between the two sensors. The surface charge sensor responds to electromagnetic radiation from 100 kHz to 1 GHz. The high frequency sensor responds to frequencies from 300 MHz to 100 GHz. The low frequency sensor, in addition to the surface charge sensor, has a vertical dipole. This dipole functions over the range of 10 MHz to 1 GHz for operation in vertically polarized fields. Horizontally polarized fields are monitored by the surface charge sensor when the wearer turns and the field is perpendicular to the sensor disc surface. The monitor functions as a protection device for horizontal, vertical and radial fields below 1 GHz. Above 1 GHz the sensitivity to radial fields is reduced, even with the 90 degree rotation of the wearer. Radial fields above 1 GHz are not significant as a potential hazard, since they predominate for less than 1/6 of a wavelength from the radiator. The frequency response of the monitor is shaped to the MPE of one of the exposure standards. Both sensors operate in their square law region. The alarm threshold varies with frequency and is appropriate for each standard independent of frequency or the number of signals. The control circuit incorporates a microprocessor that permits data logging, dual thresholds, and the ability to adjust both alarm levels, and logging rate.



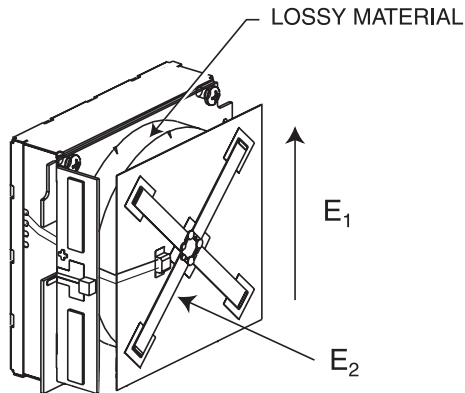
The assembly drawing shows the complete sensor assembly. It consists of three independent sensors. The low frequency region (0.1-1000 MHz) is monitored by a surface charge sensor responsive to radial E fields. The radial E field at short distance from the radiator predominates to a distance of 1/6 of a wavelength or has a magnitude of the same order as the tangential field. The surface charge sensor also responds to horizontal polarized fields when the sensor is oriented at right angles to the Poynting vector.



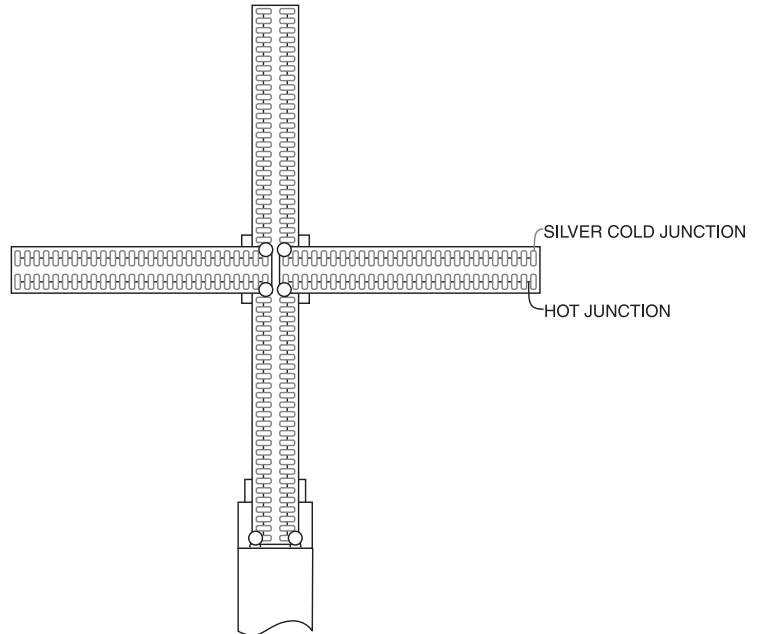
Front to Back: Nardalert S3 hooked up to a personal laptop, Instruction Manual and NBM-TS Software, and Soft Carrying Case



## Electromagnetic Radiation Monitor



DISSIMILAR RESISTIVE METALLIC FILMS



The surface charge sensor functions when the electric field is perpendicular to the surface of the sensor. This produces a time varying charge on the parallel surfaces of the sensor, with a resultant current which correlates with the rate of change of the electric field in the dielectric between the conductive surfaces of the sensor.

In the 10 MHz to 1000 MHz region, the vertically oriented dipole will respond to vertically polarized fields. The dipole and the surface charge sensor have filter networks or shaping circuits positioned between their outputs and their detector diodes. These circuits alter the frequency response to correspond to the exposure standard.

The high frequency region, 1 to 100 GHz, is monitored by the thin film thermocouple dipole antenna, which is both antenna and detector.

The surface charge sensor is separated from the high frequency thermocouple sensor by layered lossy material, having resistivities of 600 ohms - cm and 2500 ohms - cm.

For the E field parallel to the lossy material ( $E_1$ ), loss and dissipation in the material will be far greater than the loss and dissipation for the E field ( $E_2$ ) that is perpendicular to the lossy material. The lossy material at low frequencies is virtually transparent.

The high frequency elements are thin film high resistance dipoles normal to the E field that is to be sensed by the surface charge sensor. As such, they too will appear transparent.

At higher frequencies the lossy material will be effective and dissipate energy, reducing the scattering from the surface charge sensor.

The entire unit has a high resistance coating in the order of 300 k ohms/square. This prevents false triggering due to electrostatic discharge, but will not affect the frequency response.

The equivalent circuits of the three sensors each contain shaping circuits to adjust sensitivity over the frequency range to conform to the FCC standard, or any other standard such as the IEEE, or ICNIRP.

The lumped equivalent circuit of the thin film thermocouple appears as a low "Q" resonant circuit. Adjusting the element resistance determines where the low frequency roll-off will occur. Each dipole of the element is made of a series of resistive thermocouples. The cold junctions are conductive silver films having a geometry equal to a fraction of a square. They will not dissipate any RF energy, and will therefore remain cold. The hot junctions are fabricated of resistive dissimilar metallic films. They will dissipate energy with a resultant increase in temperature and the generation of a thermoelectric voltage. The hot and cold junctions are separated by a distance of less than one millimeter and therefore will be independent of ambient conditions.

In the surface charge sensor, sensor R8 provides the roll-off in the frequency response of the monitor above 1000 MHz. The combination of resistor R1, capacitor C2 and the parallel



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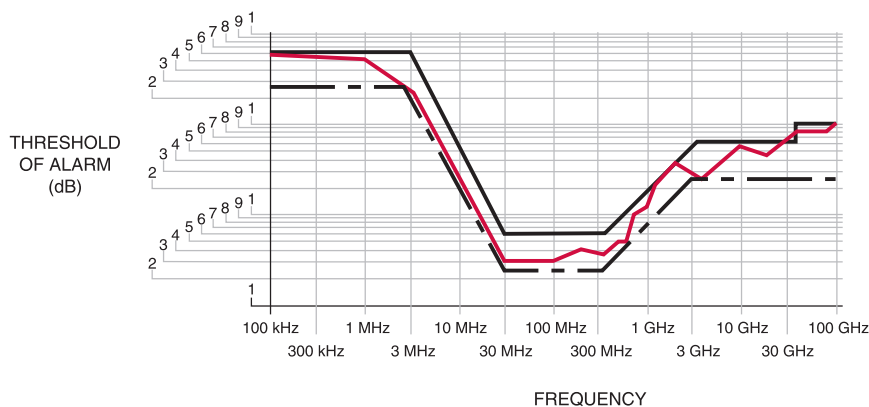
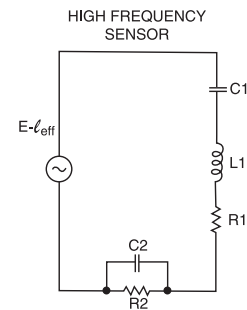
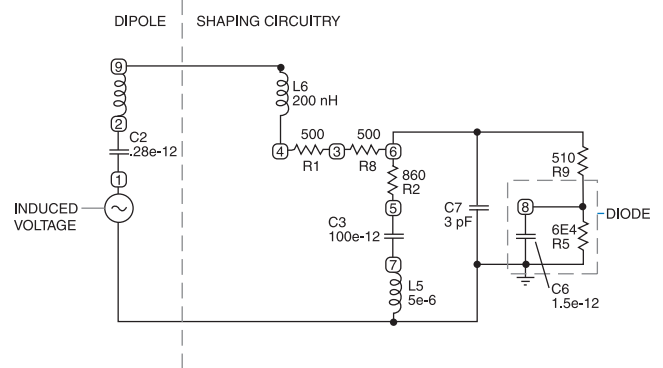
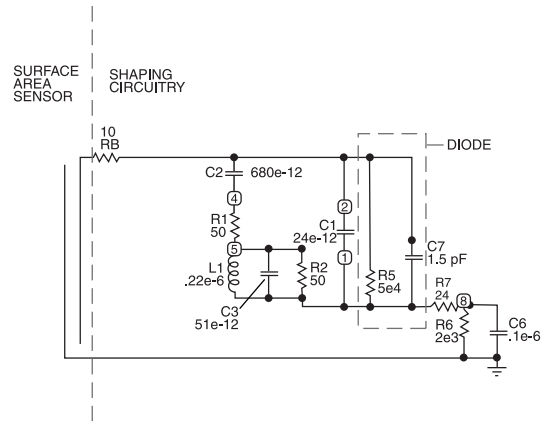
arrangement of capacitor C3, L1 and resistor R2 provides the low frequency roll-off below 30 MHz. Capacitor C1 across the detector diode provides the flat response between 30 and 300 MHz. The flat response below 3 MHz is determined by C2. The dipole mid-frequency sensor is a resistive dipole that contains circuitry to mirror the FCC standard.

The dipole resistances R1 and R8 together with capacitor C7 provide the high frequency roll off. Components R2, C3, and L5 provide the required frequency response from 3 MHz to 30 MHz of 20 dB per octave. The flat response from 30 MHz to 300 MHz is provided by capacitor C7 and the dipole capacitance C2.

The frequency response of the monitor is shown with the FCC standard and the  $\pm 3$  dB tolerance bracketing the response curve. The theoretical useful measurement range extends to about 140 GHz. Its performance at 94 GHz was confirmed at Brooks AFB in San Antonio, Texas (see application note "Making Measurements from 50 GHz to 100 GHz").

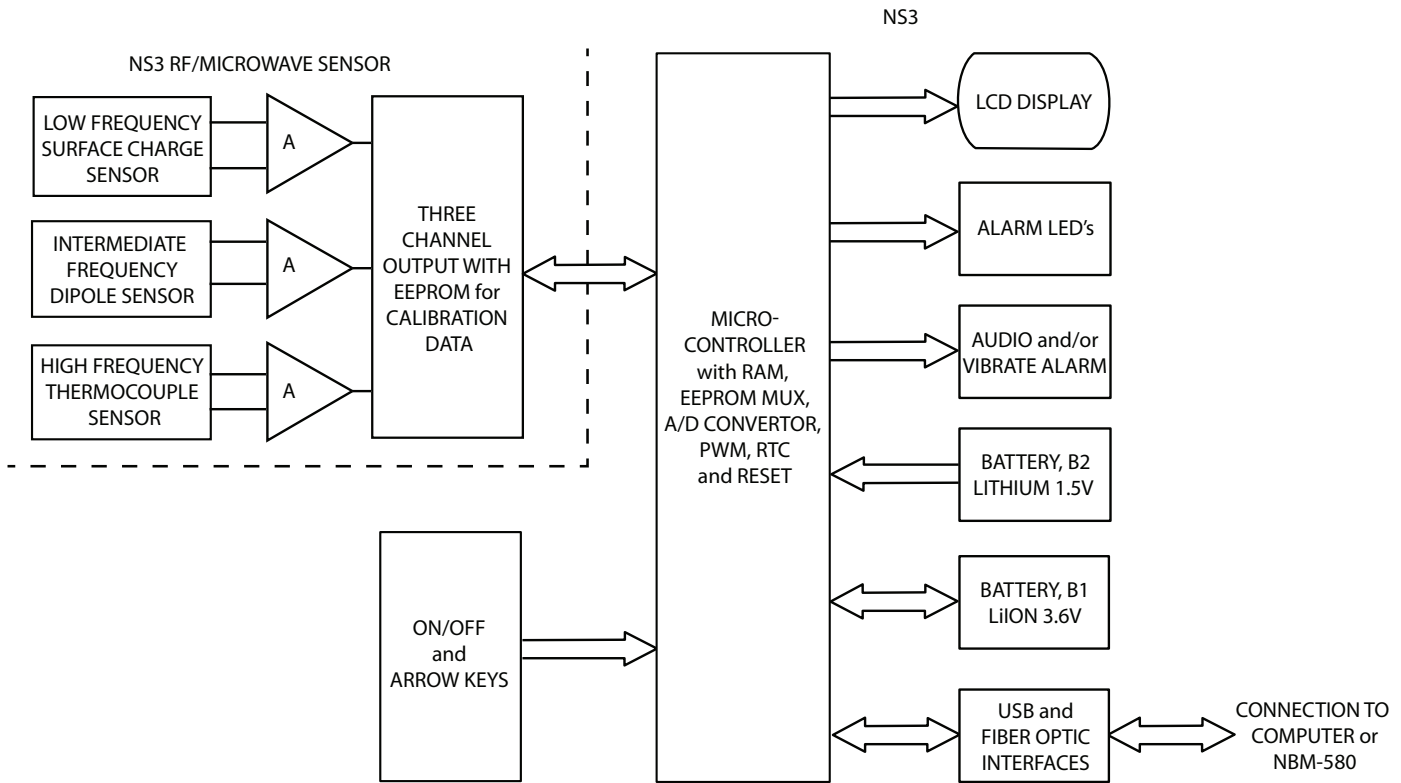
The internal circuits operate from a 3.6 V regulated supply powered by an RCR123 battery. A separate 1.5 volt button cell powers the real time clock circuit. The audio and vibrator alarms, which draw the most current, operate directly from the RCR123 battery.

The three sensor inputs feed three low noise operational amplifier circuits. The output of these three circuits are calibrated in terms of Percent of Standard. The monitor makes 32 measurements per second. The entire system operates on a 0.25 second basis. The four, 0.25 second average percentages are summed by the microprocessor to determine what level is displayed, whether an alarm is activated, and which values are stored as a part of the data logging function. Data is stored in a non-volatile memory.





## Electromagnetic Radiation Monitor



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### EDWARD ASLAN

The measurement of electromagnetic energy had its beginnings in 1968 when Ed Aslan accepted the FDA's (U.S. Food and Drug Administration) challenge to come up with a device to measure leakage from microwave ovens. Model 8100 met that challenge and brought the first of 57 patents (32 are U.S. patents). A three-time recipient of the Industrial Research 100 Award, IMPI Fellow since 1995, and IEEE Fellow since 1998, this father of the industry has earned more than 95% of the world's patents relating to the detection of RF radiation that define Narda as the recognized leader in non-ionizing radiation safety equipment.