# OPERATING AND MAINTENANCE INSTRUCTION MANUAL

# MODEL 530

## FM-STEREO MODULATION ANALYZER

INOVONICS
INCORPORATED

- USER'S RECORD -

Model 530 - Serial No.__________

Date Purchased ______________

Warranty Card Mailed __________

# OPERATING AND MAINTENANCE INSTRUCTION MANUAL

# MODEL 530

## FM-STEREO MODULATION ANALYZER

January, 1995

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# Section I

# INTRODUCTION

## MODEL 530 PRODUCT DESCRIPTION

**General**

Inovonics' Model 530 Modulation Analyzer (or *Mod-Monitor*) combines a wideband, laboratory-grade FM tuner with precision demodulation and display circuitry. The high degree of accuracy and resolution designed into the 530 qualify it for use as a station's primary means of monitoring carrier deviation (total modulation), and for quantifying other broadcast signal parameters.

The 530 is fundamentally an "off-air" monitor, inherently subject to certain limitations with respect to some measurements. These limitations can hold true for "direct" RF samples fed to the alternate, high-level input as well. These limitations are discussed in detail at the end of Section III, on Page 27.

**Model 530 Versions**

U.S. broadcasters customarily note Total Modulation measurements in *percentage,* with 100% equal to ±75kHz carrier deviation. European convention, on the other hand, is to deal directly with the kHz-deviation figures. The 530 has thus been made available in two distinct versions. The 530-00 is to the U.S. standard with Total Modulation shown in percent. The 530-01, or "530/EURO," displays Total Modulation as ±kHz of deviation. Except for scale markings, program de-emphasis jumpering and the AC mains voltage selection at time of shipment, the two versions are identical.

**FCC Type Acceptance**

Modulation Monitors used by U.S. broadcasters no longer require "type acceptance" by the Federal Communications Commission. Manufacturers have been relieved of the obligation of proving to the FCC that their Mod-Monitor designs meet specific standards for accuracy, stability and readability. Though rules pertaining to *monitoring equipment* have been relaxed or abandoned, the broadcaster remains responsible to ensure that his *transmitted signal* conforms to current FCC regulations.

Rules are frequently subject to interpretation; a fact no less true for something as apparently well-defined as FM carrier deviation measurement! More on this appears elsewhere in the Manual text.

**Features**

Features of Inovonics' 530 include:

- Separate signal inputs for antenna and for a direct-coupled, high-level RF sample.
- Frequency-agile tuner with eight station presets (memories) to facilitate *comparative* as well as *absolute* modulation measurements.
- Three measurement ranges for Total Modulation, plus an adjustable Peak Flasher. Peak integration is user-selectable.
- Remote alarms for loss of carrier and loss of audio. Front-panel and remote indication of insufficient signal strength or excessive multipath, either of which can invalidate modulation measurements.
- 80dB measurement range for demodulated program level and noise readings.
- Built-in provision to monitor measurements and alarms at a remote location.

# MODEL 530 TECHNICAL SPECIFICATIONS

**TUNING RANGE:**
87–109MHz continuous coverage; 8 station presets.

**RECEIVER SENSITIVITY:**
15μV (35dBf) for 20dB mono quieting. 250μV (60dBf) required for valid Total Modulation reading.

**RF INPUTS:**
1. "F" connector for 75-ohm antenna.
2. "BNC" connector for alternate 50-ohm RF sample; 10 volts r.m.s., max.

**RECEIVER CONTROLS/INDICATORS:**
SYNTONY (tuning) indicator
LOW SIGNAL indicator
MULTIPATH indicator
STEREO PILOT indicator
DE-EMPH ON/OFF button/indicator
MONO button/indicator
STATION SELECT buttons/indicators (8)

**CARRIER MODULATION DISPLAY:**
Quasi-peak response with peak-hold display. User-selectable integrations of 0.1ms, 0.2ms, 0.5ms, 1ms. Bargraph display monitors +peaks, −peaks, ±peaks and 19kHz Stereo Pilot. Total Modulation measurement accuracy is ±1%,±1 metering division.

**DISPLAY SCALING:**
530-00 (U.S. Version) MODULATION: 75% to 120% in 1% increments, 30% to 150% in 2.5% increments, and 3% to 15% in 0.25% increments. 100% modulation corresponds to ±75kHz carrier deviation.
530-01 ("EURO" Version) DEVIATION: ±50kHz to ±95kHz in 1kHz increments, ±10kHz to ±120kHz in 2.5kHz increments, and ±1kHz to ±12kHz in 250Hz increments.

**PEAK FLASHER:**
Adjustable between 90% and 115% Total Modulation (-00 version) or ±67kHz and ±87kHz Total Deviation (-01 version); remote flasher logic output.

**COMPOSITE INPUT/OUTPUT:**
Rear-panel BNC connector and IN/OUT switch permit external monitoring of baseband signal from off-air source, or provide input to stereo demod and metering for external baseband feed. Approx. 2 volts p-p corresponds to 100% modulation. 75-ohm output impedance; 47k-ohm input characteristic.

**BASEBAND RESPONSE:**
Amplitude response of demodulated Composite signal: +0, −0.5dB, 10Hz−70kHz; −1.5dB at 100kHz. (See Figures 1 and 2)

**DEMOD METERING:**
Dual bargraphs display L/R, L+R/L−R, 19kHz/38kHz, SIGNAL LEVEL/MULTIPATH. Quasi-peak response on +10dB to −39dB scale, averaging response with additional 30dB gain on −20dB to −69dB scale. 1dB/step metering resolution.

**STEREO DEMOD PERFORMANCE:**
PROGRAM AUDIO RESPONSE: ±0.5dB, 20Hz−15kHz.
NOISE: Unmodulated (stereo) carrier noise better than 70dB below 100% modulation with deemphasis ON.
STEREO SEPARATION (COMPOSITE INPUT): typically greater than 50dB, 50Hz−15khz (see Figure 3).
STEREO SEPARATION (OFF-AIR): typically greater than 40dB, 50Hz−10kHz (see Figure 4).
CROSSTALK MEASUREMENT: M/S and S/M crosstalk measurement by stereo sum/difference method, thus limited by stereo decoder circuitry. 50dB measurement resolution below 5kHz (see Figure 5).

**PROGRAM SIGNAL DEEMPHASIS:**
Switchable IN/OUT from front panel; -00 version is jumpered for 75μs, -01 version for 50μs.

**AUDIO OUTPUTS:**

1. Front-panel headphone jack monitors program audio.
2. 0dBu unbalanced outputs at rear-panel BNC test connectors.
3. 0dBm, 600-ohm balanced program line outputs at rear-panel USER INTERFACE connector.

**USER INTERFACE:**

Measurements, indicators and alarms are brought-out to a rear-panel DB-25 connector so that any monitoring function may be duplicated at a remote location. (See complete details on Page 25.)

**POWER REQUIREMENTS:**

105–130 and 210–260VAC, 50/60Hz; 15W.

**SIZE AND WEIGHT:**

3.5"H X 19"W X 12"D (2U); 11 lbs.

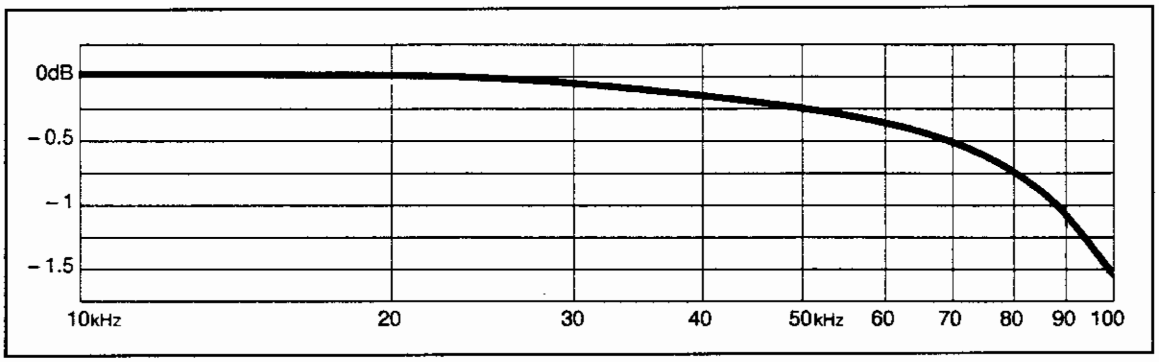



**Figure 1** - Amplitude Response of Demodulated Composite Passband

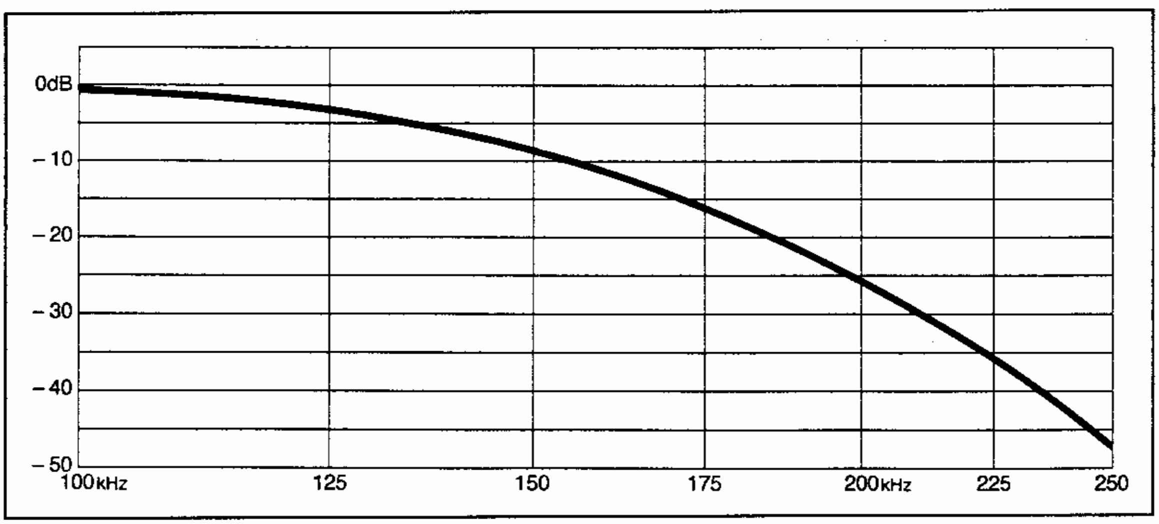



**Figure 2** - Amplitude Response of Demodulated Composite Stopband

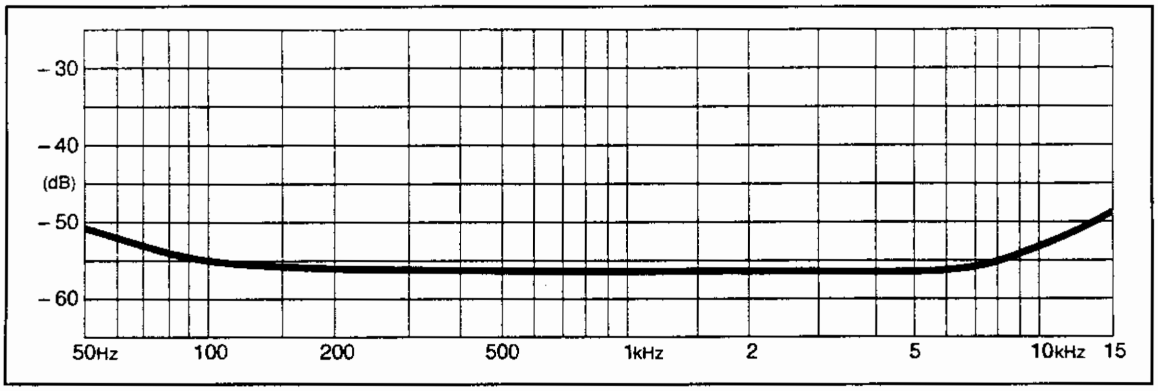



**Figure 3** - Stereo Separation From Baseband (Composite) Input

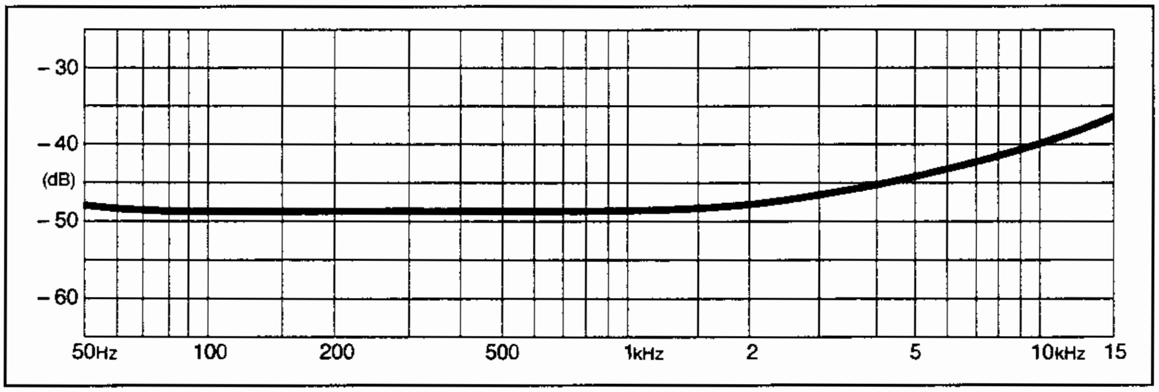



**Figure 4** - Stereo Separation From Off-Air Signal

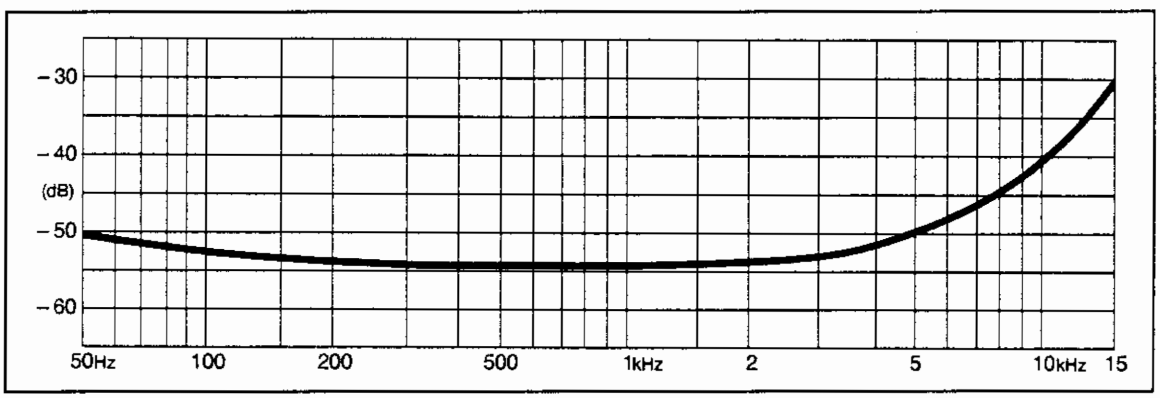



**Figure 5** - Typical Limits of M/S and S/M Measurement by Sum/Difference Method

## BLOCK DIAGRAM

A much-simplified Block Diagram of the Model 530 Modulation Analyzer is shown on the following page. Circuitry is explained in detail under Circuit Descriptions, Section IV, which references Schematic Diagrams found in the Appendix, Section V.

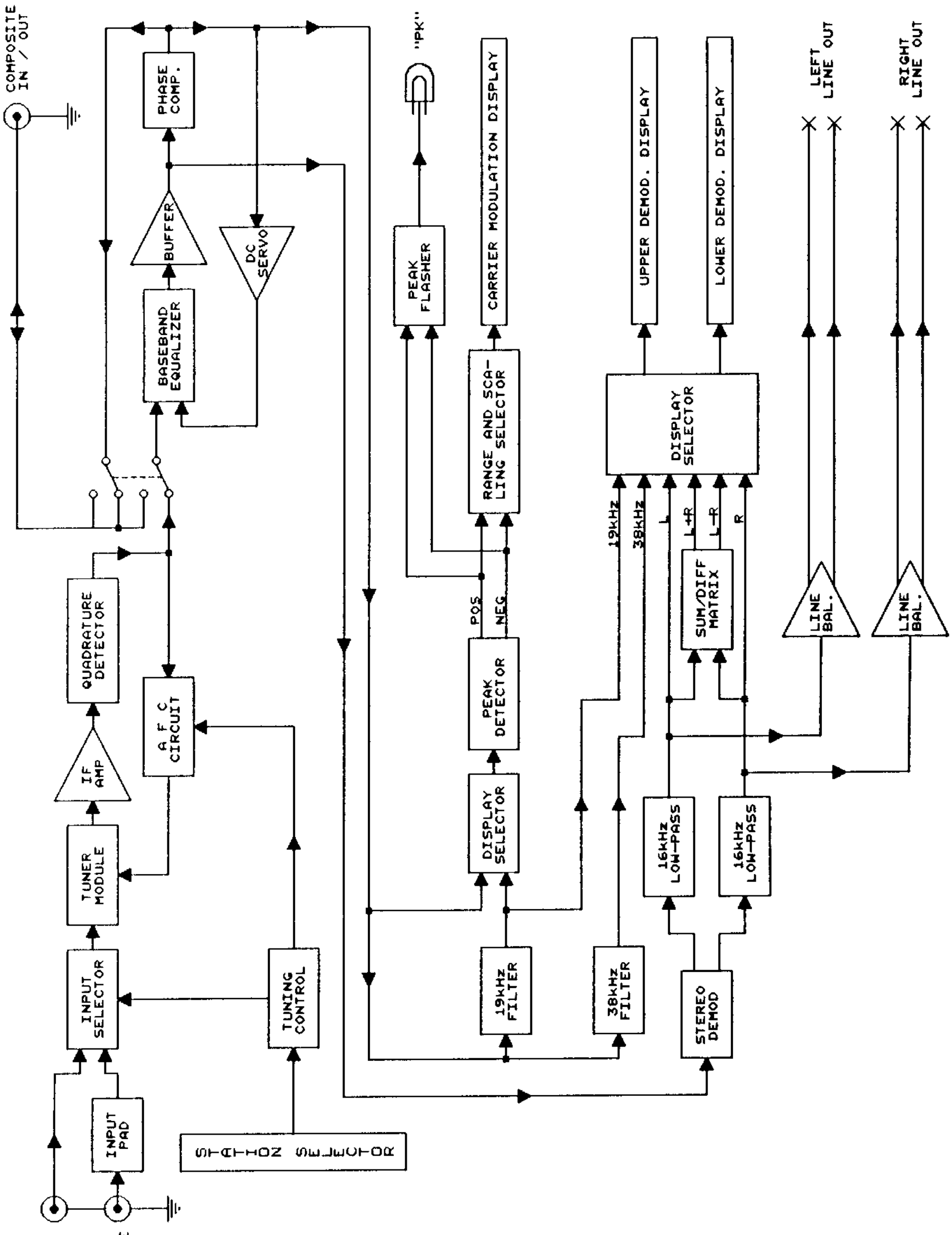



**Figure 6 -** Block Diagram, Model 530 FM-Stereo Modulation Analyzer

# Section II

# INSTALLATION

## UNPACKING AND INSPECTION

Immediately upon receipt of the equipment, inspect carefully for shipping damage. If any damage is observed, notify the carrier at once; if not, proceed as outlined below. It is recommended that the original shipping carton and packing materials be saved should future reshipment become necessary. In the event of return for Warranty repair, shipping damage sustained as a result of improper packing for return to the factory may *invalidate the Warranty!*

**IT IS VERY IMPORTANT** that the Warranty Registration Card found at the front of this Manual be completed and returned. Not only does this assure coverage of the equipment under terms of the Warranty, and provide some means of trace in the case of lost or stolen gear, but the user will automatically receive specific SERVICE OR MODIFICATION INSTRUCTIONS should they be issued by Inovonics.

## MOUNTING

**Rack Requirement**

The 530 Modulation Analyzer is packaged to mount in a standard 19-inch equipment rack and requires only 3½ inches (2U) of vertical rack space. Because the unit has no appreciable weight, only two mounting holes are provided. Nevertheless, these holes are positioned in accordance with current EIA and IEC specifications, and will align with tapped holes in all standard equipment racks. *The use of plastic "finishing" washers is recommended to protect the painted finish around the mounting holes.*

**Heat Dissipation**

The Model 530 consumes negligible power and generates insignificant heat. It is specified for operation within an ambient temperature range of freezing to 120°F / 50°C. *It is important, however, to fine-tune the 530 after it reaches its normal operating temperature.* (See "Tuning Errors" on Page 28.)

Because adjacent, less efficient equipment may radiate substantial heat, be sure that the equipment rack has sufficient ventilation to keep the temperature below the stated maximum.

## AC (MAINS) POWER

**As-Delivered**

The 530-01 (U.S. version) is factory-set for operation from 115V, 60Hz AC mains; the 530-01 ("EURO" version) from 230V, 50Hz mains. The rear-panel designation next to the fuseholder will confirm both the mains voltage selected and the value of the fuse supplied.

**Voltage Selector** A mains voltage selector switch is found beneath the top cover of the unit, adjacent to thc AC mains connector on the main circuit board. *With mains power disconnected,* slide the red actuator with a small screwdriver so that the proper mains voltage (115 or 230) is visible. You must always install an appropriate fuse, and should re-mark the rear-panel voltage/fuse designation. It is factory practice to cross out the *inappropriate* marking with an indelible black marking pen. You can remove this strikethrough with solvent to change the designation.

BE SURE that the mains voltage selector setting and primary fuse value are appropriate for the mains supply before plugging the 530 into the wall socket.

**Power Cord** The detachable power cord supplied with the 530-00 is fitted with a North-American-standard male plug. The 530-01 may either be supplied with this same cord, or with one which has no male connector. In any case, the individual cord conductors are *supposedly* color-coded in accordance with CEE standards:

BROWN = AC "HOT," BLUE = AC NEUTRAL, GRN/YEL = GROUND.

If this turns out *not* to be the case, we offer our apologies (cord vendors vary) and advise that U.S. color coding applies:

BLACK = AC "HOT," WHITE = AC NEUTRAL, GREEN = GROUND.

## RADIO FREQUENCY INTERFERENCE (R F I)

**Location** Though we anticipate the 530 to be operated adjacent to broadcast transmitters in many installations, you should exercise care in locating the unit away from *abnormally* high RF fields.

**Ground Loops** In some installation situations a mains frequency or RF ground loop may be formed between antenna or remote IN/OUT cable shield grounds and the AC power cord ground. Use of a "ground-lifting" AC adapter should remedy any problem, though the chassis ultimately must be returned to earth ground for safety.

## "DIRECT RF SAMPLE" ASSIGNMENT

The Inovonics 530 has eight station presets (tuning memories) labeled STATION SELECT 1 through 8. Position 1 is reserved for the broadcaster's own signal, and the remaining memories may be assigned to other stations in the immediate market.

**As Delivered** As delivered, the Inovonics 530 is internally jumpered to accept all eight memory input signals off-air, fed-in through the 75-OHM ANTENNA input. This means that the rear-panel DIRECT RF SAMPLE connector is *disabled,* normal for 530 installation at the studio or other location remote from the transmitter site.

When the 530 is located at the transmitter, however, you may be prefer to sample the station's signal directly, using a tap provided for this purpose in the antenna matching network. In this case, the sample point is cabled directly to the DIRECT RF SAMPLE connector (or through an appropriate pad to keep the sample below the 10-volt r.m.s. maximum). Direct feed requires a jumper change inside the 530 to activate this auxiliary input, and to assign it to STATION SELECT 1.

**Activating the DIRECT RF SAMPLE Input**

Remove the top cover and, with the front panel facing you, locate the row of integrated circuits closest to the right-hand end of the chassis. About halfway between the front and back panels you will find a jumper pin strip with a "push-on" jumper. The strip is labeled JMP4 and marked with the designations "F" and "BNC" in the circuit board artwork. These refer to the rear-panel input connector for the first memory position. When the jumper is to the *left* ("F"), tuning memory position 1 is assigned to the 75-OHM ANTENNA input, just like positions 2 through 7. With the jumper to *right* ("BNC"), the "direct" sample will be selected when the STATION SELECT 1 button is pressed. Figure 7, below, illustrates the jumpering options.

Except for input padding, the DIRECT RF SAMPLE is processed identically to a 75-OHM ANTENNA input. This means that a "direct" sample must be tuned-in just as if it were an off-air signal.

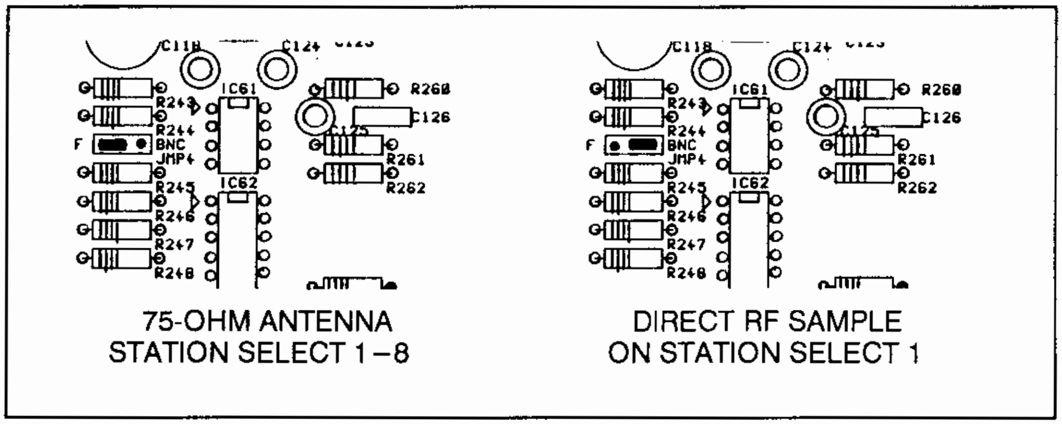



**Figure 7** - DIRECT RF SAMPLE Jumpering

## DEEMPHASIS SELECTION

The 530 accommodates both 75-microsecond (Western Hemisphere and the Orient) and 50-microsecond (Europe and Asia) FM broadcasting preemphasis standards. Deemphasis appropriate to the shipping destination is jumpered at the factory, but this is easily changed as required.

**Changing Deemphasis**

Remove the top cover and, with the front panel facing you, locate the second row of integrated circuits from the right-hand end of the chassis. About halfway between the front and back panels you will find two jumper pin strips, labeled JMP2 and JMP3, each with a "push-on" jumper. The strips are marked with the designations "75$\mu$S" and "50$\mu$S" in the circuit board artwork. You need only move the jumpers to the appropriate pins to select the desired deemphasis, as illustrated in Figure 8 at the top of the next page.

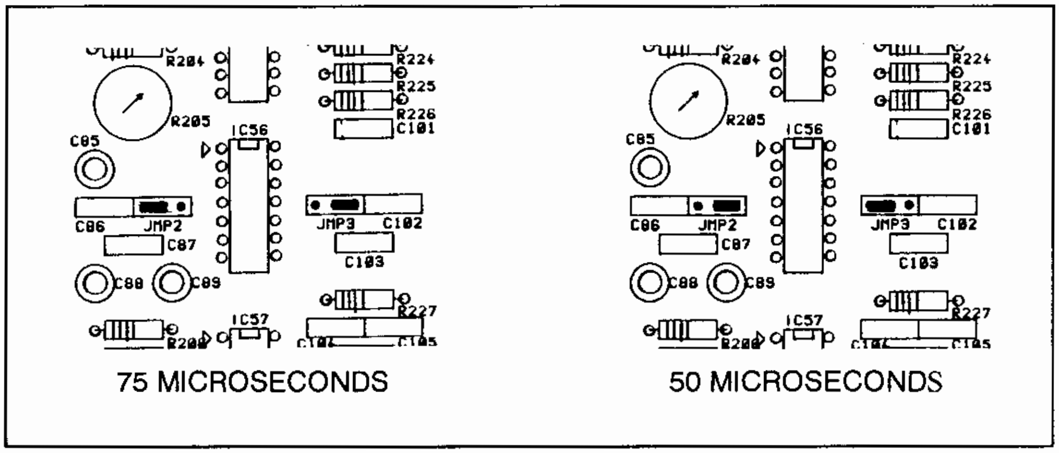



**Figure 8** - Deemphasis Jumpering

## PEAK MODULATION DISPLAY INTEGRATION SELECTION

**Integration Defined**

"Peak integration" refers to the mechanism by which carrier peak deviations lasting less than a predetermined time tend to be ignored by the measurement and display circuitry. This is one of the techniques broadcasters use to hedge a bit, squeezing that last dB of "competitive edge" (ie: loudness —?) into the signal.

Current broadcasting practices (and at least the U.S. FCC's own rules) are a bit vague on the subject of peak integration. Nearly all Modulation Monitors include some provision for ignoring exceedingly fast program peaks, sometimes referred-to as "peaks of infrequent occurrence," or some similarly nebulous catch-phrase nonsense. Certainly, *non-repetitive overshoots* which do not materially increase the broadcaster's "occupied bandwidth," and, therefore, pose no threat of interference to an adjacent-channel signal, may legitimately be ignored in a measurement of Total Modulation. But by allowing peaks resulting from, and directly related to, the dynamics of the program signal to "slide-on-by," the broadcaster is courting the wrath of the regulatory agency.

**FCC Measurement Method**

One reliable guideline in determining just "how far you can go" with respect to Total Modulation is to be aware of how the government authority monitors a broadcaster's signal. The U.S. FCC does not use a Modulation Monitor with metered readout. Instead they connect an oscilloscope to the composite baseband output of a wideband FM receiver and look for deviations beyond a known and calibrated peak-to-peak amplitude. As divulged by one Field Engineer, the FCC is not looking for the occasional overshoot, but for consistent and flagrant overmodulation which is invariably *heard* or *complained about* before it is flagged for monitoring.

**As Delivered**

The Inovonics 530 permits the user to select one of four separate integration times: 0.1ms, 0.2ms, 0.5ms and 1.0ms. As delivered, the 530 is jumpered for the fastest, 0.1ms integration time. This is the safest choice, but the one which will give the *highest* Total Modulation reading for any given signal. Offered a selection, most broadcasters will opt for a longer integration – as much as 10ms! We feel that this much integration equates to "fooling no one but yourself." The longest, 1.0ms integration time afforded by the Model 530 is *probably* safe under *nearly all* operating conditions, though the user is reminded that it's little red cars which most often get speeding tickets!

**Changing Integration Time**

Remove the top cover and, with the front panel facing you, locate the second long row of integrated circuits from the left-hand end of the chassis. About midway between the front and back panels you will find a double-row jumper pin strip with a "push-on" jumper. The strip, labeled JMP1 and PK INT, is marked with the designations "0.1," "0.2," "0.5" and "1.0" in the circuit board artwork. You need only move the jumper to the appropriate pair of pins to select the desired peak integration time, as illustrated in Figure 9, below.

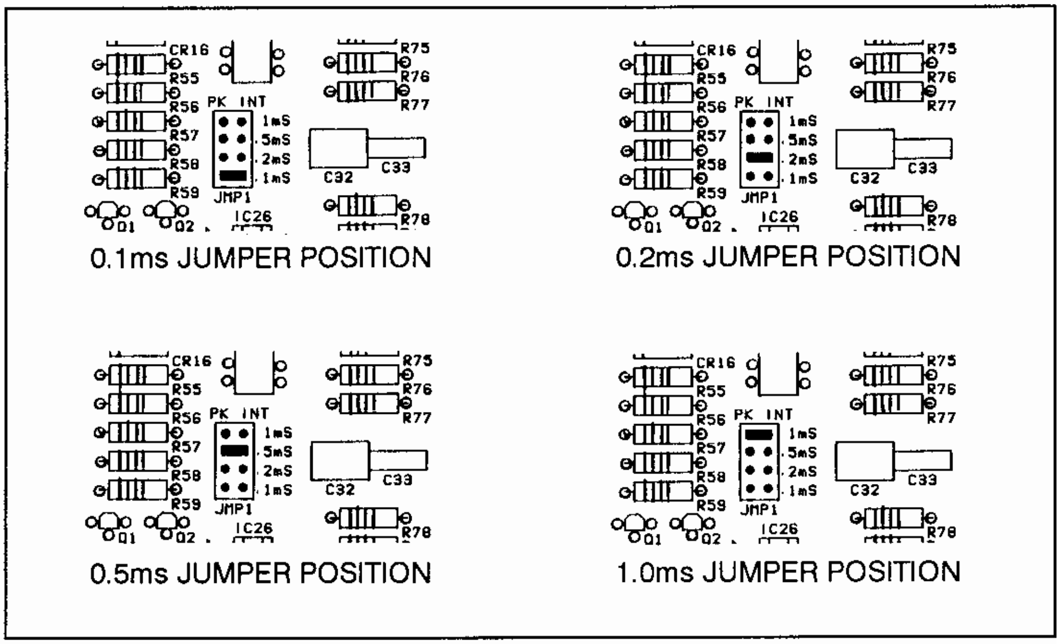



**Figure 9** - Peak Integration Jumpering

# A WORD ABOUT LOUDNESS

Radio "loudness wars" began in the U.S in the mid-1960s. This is about the same time that radio became "format-ized," and the broadcaster had to compete for advertising dollars with a growing number of stations in the same market playing the very same songs. Rather than competing for listeners on the basis of program variety, air personalities or programming quality, station owners and Program Directors grasped at technical gimmicks to attract listeners.

At some point *perceived loudness* emerged as a benchmark for broadcasting success. As if, ". . . no matter the programming, play it louder and it'll grab the listeners. If ratings slip, it's the Chief Engineer's fault!" Despite the obvious idiocy of this line of reasoning, the availability of more complex and more expensive audio processing equipment is a testament to its belief, and to the paranoia and shortsightedness of station management.

Aggressive audio processing and the accurate measurement of resulting carrier deviation are interwoven in broadcasting today. But the high degree of *technical capacity* we now so easily acquire should never be confused with *technical excellence.* Innovative, refreshing *programming* and long-term *listenability* will continue to be the keys to any station's lasting success. Honest!

# Section III

# SETUP AND OPERATION

## PANEL CONTROLS AND INDICATORS

This description of the Model 530 front panel is keyed to the number-coded illustration which appears on the next page. Following this description, a guided *Tutorial* is presented which will help you become even more familiar with the 530.

**1 POWER**

If the purpose of this switch is *not* self-explanatory, you are authorized (no, *requested!*) to return the Model 530 for a full refund of the purchase price.

**2 PHONES**

This stereo jack accommodates a pair of headphones for monitoring the demodulated program. There is no volume control for this jack, the audio level has been preset for comfortable listening with medium-impedance headphones currently popular in professional use. (The *Sennheiser HD* series, for example.) 8-ohm 'phones may be used with some sacrifice in volume.

**3 STATION SELECT**

This series of eight pushbutton switches selects the station tuned for that memory position. An LED above each button shows the current selection. The small hole **(4)** above the LED gives screwdriver access to tune the radio.

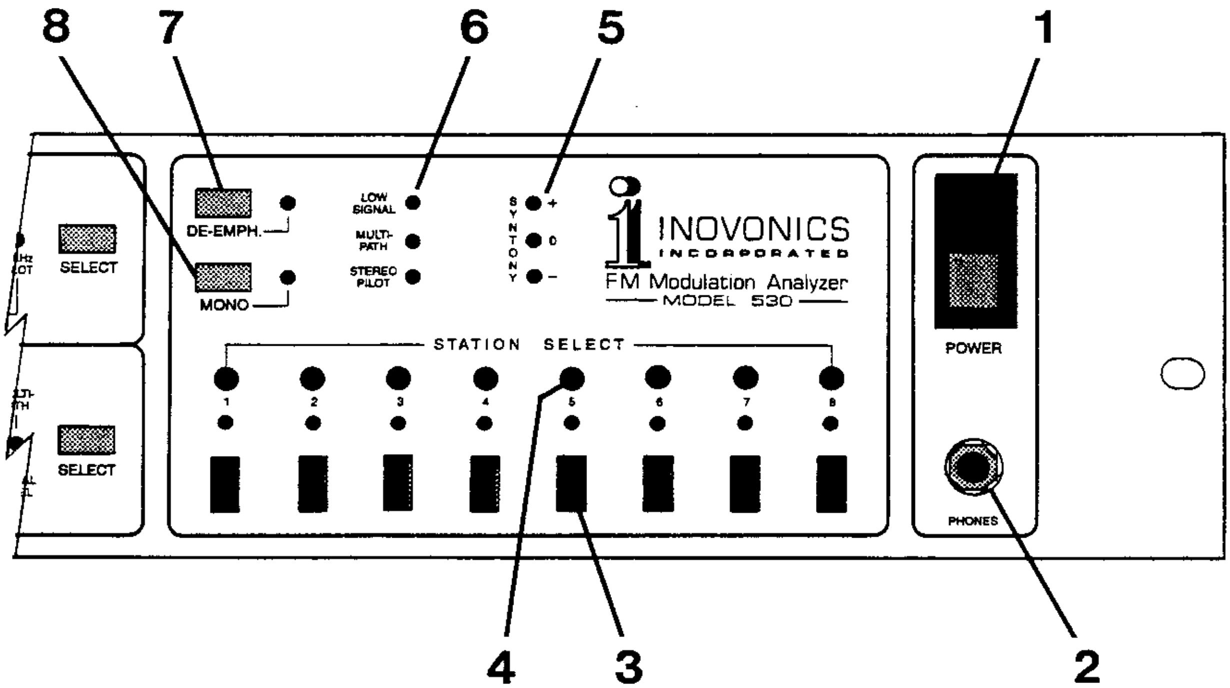
The STATION SELECT button has multiple functions. When the button is depressed and *held down,* the CARRIER MODULATION display bargraph **(9)** indicates the tuned frequency on the top-most (MHz) scale. At the same time, the 530's AFC circuit is defeated so that the station may be accurately tuned-in using the SYNTONY indicator **(5)**.

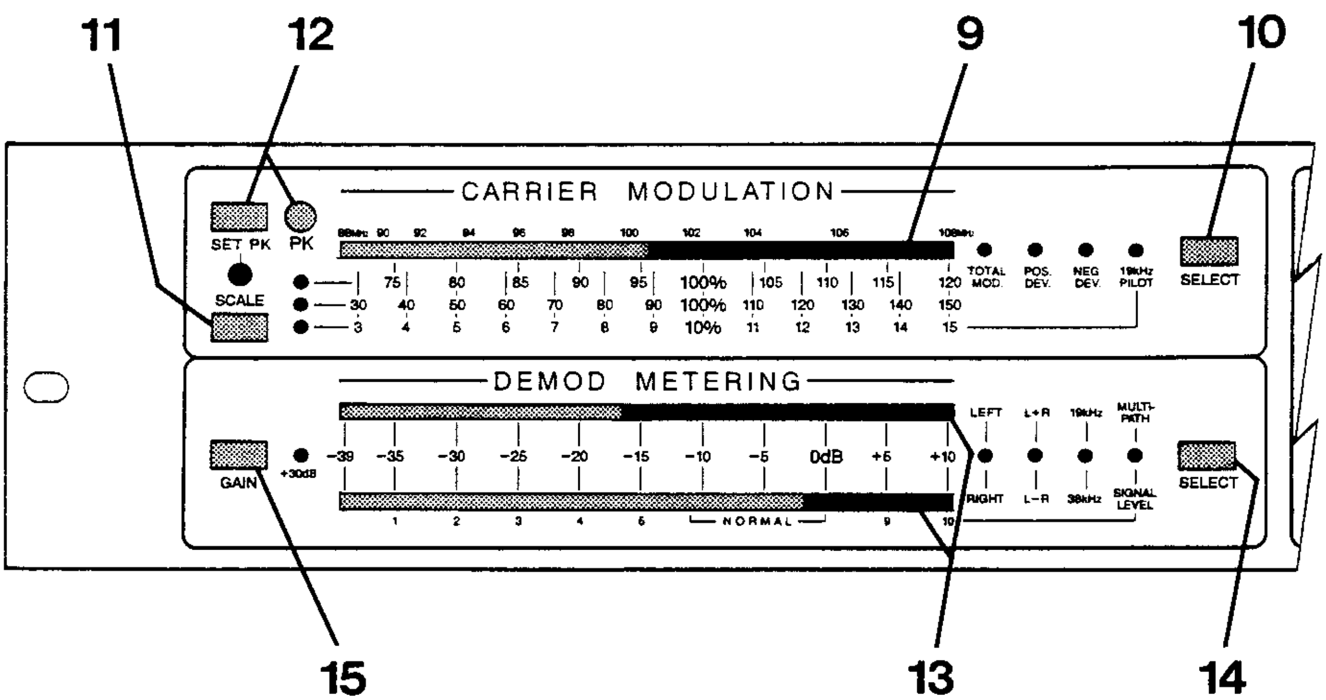
As soon as the STATION SELECT button is *released*, the CARRIER MODULATION display reverts to its normal mode, and AFC is enabled to keep the carrier tuned dead-center.

**4 TUNING**

The 530 is varactor-tuned with a DC voltage from the multiturn potentiometer **(4)** associated with each STATION SELECT button. A tenacious AFC loop holds the tuned carrier at the center of the IF passband, but as long as the STATION SELECT button is *held down,* the loop is disabled. This allows very precise tuning.

You reach the tuning pot with a small flat-blade screwdriver which will be guided into the adjusting screw by a molded-on plastic bushing. (Don't worry that you can't see anything through this hole, it's virtually impossible to miss the adjustment.)


8 7 6 5 1
DE-EMPH.
MONO
LOW SIGNAL
MULTI-PATH
STEREO PILOT
SYNTONY
+
0
−
INOVONICS
INCORPORATED
FM Modulation Analyzer
MODEL 530
STATION SELECT
1 2 3 4 5 6 7 8
POWER
PHONES
SELECT
SELECT
4 3 2


11 12 9 10
CARRIER MODULATION
SET PK
PK
SCALE
75 80 85 90 95 100% 105 110 115 120
30 40 50 60 70 80 90 100% 110 120 130 140 150
3 4 5 6 7 8 9 10% 11 12 13 14 15
TOTAL MOD.
POS. DEV.
NEG DEV.
19kHz PILOT
SELECT
DEMOD METERING
GAIN
+30dB
−39 −35 −30 −25 −20 −15 −10 −5 0dB +5 +10
1 2 3 4 5 NORMAL 9 10
LEFT
RIGHT
L+R
L−R
19kHz
38kHz
MULTI-PATH
SIGNAL LEVEL
SELECT
15 13 14

Tune the radio while *holding down* the selected STATION SELECT button. Use the top (MHz) scale of the CARRIER MODULATION display **(9)** as an *approximate* frequency indicator. (As a dial position display the readout is not absolute.) Once the station is found and roughed-in, fine-tune while watching the SYNTONY indicator LEDs. Properly tuned, the center, green LED will be lighted, with neither the + nor the − LEDs visible. When the STATION SELECT button is released, AFC is engaged and the station is locked-in.

## 5 SYNTONY INDICATOR

The word *syntony* dates from the earliest days of wireless telegraphy. It is decidedly a more melodious word than the now-common synonym *tuning,* and was chosen to grace the front panel of the 530 as a tribute to Oliver Lodge and our rich radio heritage.

The SYNTONY indicators comprise a very accurate tuning meter, showing when the received carrier is above (+), below (−) or centered (0) with respect to the receiver RF/IF/detector passband.

Whenever the receiver AFC is defeated; that is, when a STATION SELECT button is *held down,* the center, green LED should be lit to full brilliance with neither red one even faintly illuminated. To ensure greatest display accuracy, make it a habit to occasionally check for "syntonic reception" of the stations in memory during normal operation. If either red LED glows when a STATION SELECT button is held down, touch-up the tuning to center the SYNTONY indicator.

## 6 SIGNAL STATUS INDICATORS

There are two adverse reception conditions which invariably cause a false off-air measurement of Total Modulation. These are: 1) an incoming signal from the antenna which is *too low in level* for full quieting of the receiver, or: 2) a received signal accompanied by *so much multipath distortion* that true carrier deviation is impossible to resolve. Both conditions will cause a reading of Total Modulation which is *higher* than the actual value.

Red alarm LEDs **(6)** alert the operator that *readings are bogus* because of reception conditions. In addition to these go/no-go indicators, the relative value of signal level and multipath distortion may be brought-up on the DEMOD METERING bargraph readouts **(13)**.

The trigger points at which the LOW SIGNAL and the MULTIPATH indicators come on are preset, based on reception conditions which have been determined to result in a Total Modulation display error on the order of one percent (±750Hz dev.). For trustworthy *absolute* measurements, and for meaningful *comparative* measurements between stations, the LOW SIGNAL and MULTIPATH indicators must remain off when readings are taken.

The STEREO PILOT indicator responds to the 19kHz "pilot tone" which synchronizes the stereo decoder circuitry and identifies a stereophonic broadcast. This LED should light for nearly every station on the dial. The only time it might not come on is in the rare instance that the station elects to transmit monaural programming in the MONO mode for best reception in its fringe-area, or if there is trouble with the station's Stereo Generator or STL. The STEREO PILOT indicator also goes out when the front-panel MONO button **(8)** is engaged to put the Model 530 into a "forced-mono" reception mode.

### 7 DEEMPHASIS SELECTOR

FM broadcasting utilizes transmission preemphasis (high frequency boost) and complementary reception deemphasis (high frequency rolloff) to reduce the effects of noise, an inevitable component of the program signal. Two standards for the characteristic curve are in general use; "75 microseconds" for the Western Hemisphere and the Orient, and "50 microseconds" for Europe and Asia. The numbers refer to the R/C time constant which defines the turnover frequency, or inflection point. The 75μsec. curve has a 3dB point at 2120Hz, 50μsec. at 3180Hz. Either characteristic may be selected, depending on where the Model 530 is used. (See instructions on Page 10.)

Pushing the button once will turn deemphasis (and the LED) off, pushing it again turns deemphasis back on.

Deemphasis is normally on, as indicated by the green LED next to the DE-EMPH switch **(7)**. This imparts proper equalization to the received signal for a flat overall frequency response. Without deemphasis in the circuit, program audio will sound unnaturally "bright," or shrill. *Leave the function on* unless you are conducting proof-of-performance or other audio tests with transmission preemphasis similarly defeated.

### 8 FORCED-MONO RECEPTION

The Model 530 automatically recognizes and decodes standard stereophonic broadcasts. In performing some transmission tests, however, it may be necessary to turn off the stereo decoder circuitry. In this manner you can do a quick "mono compatibility" test, simulating reception by a monaural receiver, or by a typical auto stereo receiver with "blend" which gradually fades from stereo to mono reception as signal strength diminishes. (The 530 Stereo Decoder, itself, *does not* include a "blend" function.)

### 9 10 11 CARRIER MODULATION

This is the Total Modulation (carrier deviation) readout. Using the SELECT button **(10)**, the display may be cycled to show TOTAL MOD. (the normal Total Modulation display, a composite of both negative and positive carrier deviations), POS. DEV. (only the modulation excursions *above* the carrier resting frequency), NEG. DEV. (only the modulation excursions *below* the nominal carrier frequency), and 19kHz PILOT (the injection level of the Stereo Pilot). A second function of this display is the tuning dial, discussed earlier.

In the 530-00, modulation is shown as a percentage, assuming the universal standard of ±75kHz corresponding to full, or 100%, modulation. The 530-01 shows kHz of carrier deviation directly.

Three measurement ranges may be selected with the SCALE button **(11)**; the selected range is indicated by an LED at the left-hand end of each scale. The default range (upper modulation scale) gives 1%-per-step display resolution between 75% and 120% (530-00), or 1kHz-per-step between ±50kHz and ±95kHz deviation (530-01) for setting transmitter deviation limits with greatest accuracy.

Pressing the SCALE button will change the scaling to the 30% to 150% range and 2.5%-per-step display resolution (530-00), or ±10kHz to ±120kHz deviation range and 2.5kHz-per-step resolution (530-01). This selection is useful to show transmitter deviation outside the typical range of operation; for instance, to view the wide dynamics of classical music programming, or to gape in wonder and awe at transmissions which are in flagrant violation of legal limits.

Pressing the SCALE button once again will increase the gain of the metering circuit by 20dB (10X), yielding a range of 3% to 15% in 0.25% steps (530-00), or ±1kHz to ±12kHz deviation in 250Hz steps (530-01). This range is useful for setting RDS or SCA subcarrier injection levels. Since this is still a display of Total Modulation, however, the program signal and the Stereo Pilot *have to be turned off* so that the subcarrier is the *only* modulation indicated. (See the discussion covering subcarrier measurement on Page 24.)

When the SELECT button **(10)** is cycled to display the 19kHz PILOT injection level, the bottom scale (3% to 15% or ±1kHz to ±12kHz deviation) is automatically selected. The Stereo Pilot is measured through a narrow bandpass filter so that the reading is accurate in the presence of normal program modulation.

Carrier Modulation metering has *peak* response to carrier deviation, with integration determined by internal jumpering as discussed on Pages 11 and 12. The display also has a peak-hold function which causes the bargraph to linger for a fraction of a second when it is updated by a program peak. This gives adequate visual display of even the briefest carrier excursions.

## 12 PEAK FLASHER

The adjustable Peak Flasher may be set to give an obvious visual indication (or remote alarm) whenever Total Modulation reaches the preset value, even if for only the briefest instant. The Flasher response to modulation peaks (integration) is the same as for the Carrier Modulation display. Flash duration of the PK indicator is approximately one second.

The Flasher is set while *holding down* the SET PK button. This causes the Carrier Modulation bargraph to display the

Flasher trigger point, which can then be set by engaging the adjustment potentiometer through the hole directly below the SET PK button **(12)** with a small screwdriver. The Carrier Modulation SCALE button **(11)** should be cycled for highest resolution (upper modulation scale) while the Peak Flasher is being adjusted.

### 13 14 15 DEMOD METERING

This dual bargraph meter may be cycled with the SELECT button **(14)** to display LEFT and RIGHT program audio, the L+R stereo signal sum and L−R stereo signal difference, as well as 19kHz Stereo Pilot and 38kHz "residual" modulation components—all with dB-linear scaling referred to 100% (±75kHz dev.) carrier modulation. The normal scale shows +10dB to −39dB in 1dB steps. Pressing the GAIN button **(15)** introduces 30dB of measurement gain, shifting the scale downward to read −20dB to −69dB instead.

In the normal program signal range (0dB reference), metering (ballistic) response is "quasi-peak" to best show correlation between program audio and total carrier modulation. When increased gain is switched into the circuit (−30dB reference), the meter has an *averaging* response to render a steadier, more meaningful presentation of low level signals and residual noise.

LEFT and RIGHT channel metering is for normal program monitoring and for making stereo separation and noise tests. Separation is generally measured with DE-EMPH. **(7)** OFF, and with transmission preemphasis similarly defeated.

System crosstalk (sub-to-main and main-to-sub) is measured using the stereo sum-and-difference method. The stereo decoder translates the "main" and "sub" channels into L+R and L−R, respectively. These measurements must be taken with the 19kHz Stereo Pilot ON, and with DE-EMPH. **(7)** OFF. (Note the crosstalk measurement limitations graphed in Figure 5 on Page 6.)

The remaining meter selection, MULTIPATH and SIGNAL LEVEL, gives only a *relative* display of these two reception parameters. Except for a NORMAL range of off-air or directly-coupled SIGNAL LEVEL (marked below the lower bargraph), neither display is calibrated, nor is it dB-linear. Since there is a go/no-go LED **(6)** for LOW SIGNAL and MULTIPATH, the analog displays are mainly used for aiming a directional antenna, or in determining just how bad reception conditions actually are.

## A GUIDED TOUR OF MODEL 530 OPERATION

This short "hands-on" tutorial walks you through setup and typical operation of the Model 530. By taking this informal guided tour, you will gain a first-hand understanding of procedures and pitfalls which may well prove useful in formal day-to-day use of the unit.

Numbers shown in the text of the tutorial refer back to the keyed photo of the Model 530 front panel on Page 14.

**Items Required**

You'll need a pair of good stereo headphones and a 3-foot length of small-gauge, insulated hookup wire, stripped-back about half-an-inch on one end. Also a small flat-blade screwdriver which will pass through the front-panel tuning holes **(4)**.

**Getting Ready**

Attach the power cord to the Model 530 and plug the free end into the wall socket. Plug the headphones into the front-panel PHONES jack **(2)**. Tightly twist the stripped end of the 3-foot wire and *carefully* insert it into the very center of the rear-panel "F" connector labeled 75-OHM ANTENNA. Do not force this! If it doesn't fit easily and hold securely, use a piece of wire that does. Check to make sure that the small slide switch next to the back panel COMPOSITE IN/OUT connector is to the *right,* or NORM. position.

**Power ON**

Turn the POWER switch **(1)** on. The 530 always powers-up to STATION SELECT (memory) position 1. After a short delay you should hear inter-station hiss, unless the 530 left the factory tuned to an active frequency in your area.

**Tuning In**

Insert your small screwdriver through the tuning hole **(4)** above STATION SELECT button 1. Press and *hold down* button 1 while turning the screwdriver slowly clockwise.

As you turn the screwdriver, observe the CARRIER MODULATION (top) LED bargraph **(9)** following the rotation. Note also that the screwdriver is adjusting a *15-turn potentiometer,* and requires about the same number of rotations to take you from the bottom (88MHz) to the top (108MHz) of the FM dial.

Find a strong, local station. If your own signal cannot be picked up easily at the present location, choose a station which does come in well. Remember to hold down the STATION SELECT button while tuning. Watch the three SYNTONY indicators **(5)** and fine-tune the signal so that only the green LED is lit. Once you're tuned, release the STATION SELECT button and AFC will lock the station in.

If you like, you may set some of the other station memories as well. Again, for the purpose of this demonstration it's best to choose strong, local signals. Set the other memories just as you did Number 1, holding down the memory buttons (2, 3, and so-on) while each signal is tuned-in.

**Signal Quality Evaluation**

With a local station tuned, check the LOW SIGNAL and MULTIPATH indicators **(6)**. Depending on how well the station is actually received, one or both of these may be on.

Locate the SELECT button **(14)** associated with the DEMOD METERING display **(13)**. When the 530 is first turned on, the two bargraphs will show LEFT and RIGHT program audio channels. Pressing the SELECT button once will change the display to L+R (stereo program *sum*) and L−R (stereo program *difference*.) A second push will allow you to monitor 19kHz Stereo Pilot and 38kHz (stereo subcarrier) residual. Press the SELECT button once more to bring up the MULTIPATH and SIGNAL LEVEL metering.

Even with a 3-foot wire as an antenna, a local station should indicate in the NORMAL range of the bottom SIGNAL LEVEL bargraph. The MULTIPATH readout, above, on the other hand, is another matter entirely.

Grab the free end of your 3-foot antenna and slowly wave it about. Try it straight up, hanging off the table, and held horizontally pointing in various directions. Unless you are sitting directly under the transmitting antenna, the MULTIPATH bargraph should respond to different antenna orientations with greater or lesser readings of indicated multipath distortion. Under optimum reception conditions the MULTIPATH readout will drop nearly off-scale and the MULTIPATH warning indicator **(6)** will go out.

When the 530 is in actual Mod-Monitor service, the two warning indicators *must be off* if measurements are to be trusted. This usually calls for a direct feed from your own transmitter (see Page 9), or a rooftop antenna with a rotator for meaningful comparative measurements of other stations in the market. For right now, try to position your antenna wire so that both the LOW SIGNAL and the MULTIPATH warning lights **(6)** are off. If this is not possible with the station tuned, try another local station. Once you have reliable reception, press the SELECT button **(14)** once more to return the twin bargraph metering to LEFT and RIGHT program audio.

**Program Deemphasis**

While listening to off-air program audio, press the DE-EMPH. button **(7)**. The LED next to the button will go out, and program audio will sound considerably "brighter," even to the point of shrillness. Pressing the button again will turn deemphasis back on. As you cycle program deemphasis on and off you may notice that, although the audio sounds quite different, the LEFT and RIGHT program audio displays **(13)** do not change much, if at all. Despite the very audible difference, there is very little musical *energy* at the high frequencies; it's the subtle overtones which are boosted out of proportion without proper deemphasis.

Unless you are doing system crosstalk or other proof-of-performance test which requires "flat" program audio metering, the proper way to leave the DE-EMPH. selection is with the indicator LED on. After listening for a bit with deemphasis off, proper tonal balance may sound a bit "dead." This notion will pass after listening properly again for a short while.

**Forced Mono Reception**

Use the SELECT button **(14)** to cycle DEMOD METERING to L+R and L−R, the sum and difference, respectively, of the Left and Right stereo program channels. Unless something is very wrong (including one channel missing entirely), the L+R sum will always have more energy than the L−R difference. In practical, real-world situations, this is true with all recorded music. Two notable exceptions are: 1) pop music which has been processed with "spatial enhancement" devices which augment the stereo difference information, and: 2) classical music which has been recorded as true binaural using only two microphones. (Almost all pop music is recorded monaurally in the original session and mixed to create artificial stereo during the mix-down process.)

In isolated instances the L+R and L−R meters may be close in value, but the L−R meter will generally lag the L+R meter by at least a few dB. For voice announcements without background music, the L−R indication may drop off the scale entirely!

Press the MONO button **(8)**. This will light the adjacent red LED. With (forced) MONO engaged, the stereo decoder in the receiver circuitry is disabled and the station is received monaurally, with Left and Right program channels equally combined.

Two things to notice in the MONO mode: 1) a "night and day" difference in the sound, especially monitored with headphones. The stereo image will "collapse" and much of the detail may be lost from the music. It may even sound as if the top-end rolls off. Also: 2) the L+R meter will jump up a bit in MONO, but the L−R meter will drop completely off the scale.

While monitoring L+R and L−R in MONO, press the GAIN button **(15)**. The indicator next to the button will light showing that the meter circuit now has an additional 30dB of gain, or that the scaling has changed from a range of +10dB to

−39dB, to a range of −20dB to −69dB. With normal modulation the upper L+R meter will stick at the top, since program audio would have to fall to −20dB to remain on-scale. The L−R meter will read −25dB or lower on the scale, which, because of the increased range, is actually −55dB. Although a perfect monaural signal should have *no* L−R component, circuit and component tolerances within the 530 make −55dB close to the best cancellation possible. Keep this in mind because −55dB is about the best sub/main, main/sub crosstalk reading you will see on the 530, even though actual system crosstalk may be lower. (See Figure 5 on Page 6.)

**Peak Flasher Set**

Refer now to the CARRIER MODULATION display **(9)** which, because of its power-on "wake-up" state, should be showing TOTAL MOD. on the upper, 75% to 120%, or ±50kHz to ±95kHz deviation, modulation scale.

Press and hold down the SET PK button **(12)**. The display will stop following carrier modulation and hold at some value close to mid-scale. Stick your small screwdriver through the hole directly below the SET PK button, and rotate the adjustment potentiometer from one end to the other. This pot is a single-turn control, and you will be able to set the display between about 90% and 115%, or ±67kHz and ±87kHz deviation. Carefully set the bargraph readout at precisely 100%, or ±75kHz. When the SET PK button is released, the large, red PK (Peak Flasher) LED will blink each time carrier modulation reaches this value.

If the station you have tuned-in is modulating "aggressively," the Peak Flasher set at 100% (±75kHz dev.) may never turn off! If this turns out to be the case, you may wish to reset the Peak Flasher to a slightly higher figure. The ultimate setting of the Peak Flasher will depend upon whether your station has one or more subcarriers, and upon just what modulation limits you choose to impose on your broadcast signal. A Peak Flasher is generally set for a value *just above* the maximum allowable deviation. When set at this point, it should rarely blink.

**CARRIER MODULATION Ranges**

While watching TOTAL MOD. on the top, highest resolution scale, press the SCALE button **(11)** once. This will change the scaling to the 30% to 150% (or ±10kHz to ±120kHz dev.) range. If the program was initially kicking the 530-00 up to 107%, or 8 meter segments above 100%, it will now show the same value at 3 or 4 segments above 100%. The 530-01, initially peaking at ±80kHz deviation, or 5 meter segments above ±75kHz deviation, will now peak 2 segments above ±75kHz. You will also notice that the "fallback" of the meter seems slower on this range. Ballistics haven't changed, it's only that the meter travels a shorter distance in the same time period.

On the expanded range, resolution of a 530-00 is 2.5%-per-step instead of 1%-per-step; a 530-01 has 2.5kHz deviation increments instead of 1kHz. Peak Flasher calibration remains unchanged, however. If the SET PK button **(12)** is held down on the expanded range, it will still show the same flasher setting, only with less resolution (accuracy) than on the upper scale. This range/resolution tradeoff demonstrates why the 530 should always be kept on the upper scale for best accuracy.

If the SCALE button is pressed once again, metering sensitivity is increased by 20dB. The 530-00's 100% point is now 10%, and resolution is 0.25%-per-step; 530-01 deviation measurement is 250Hz-per-step. While measuring TOTAL MOD. on this bottom scale, the meter will simply slam to the top and stay there. Total carrier modulation would have to drop to 15% modulation (530-00) or ±12kHz deviation (530-01) to be on-scale.

While watching TOTAL MOD. on the upper, high resolution scale, cycle the SELECT button **(10)** between TOTAL MOD., POS. DEV. and NEG. DEV. Under ideal reception conditions you probably won't see any appreciable difference in the display unless something is very much amiss in the station's audio processing system or exciter. The human voice is naturally very asymmetrical, and lightly-processed solo speech or voice announcements without background music can show significantly greater deviation in one direction. (See also "Adjacent Station" notes on Page 28.)

**Pilot Injection Metering**

When the SELECT button **(10)** is cycled to the 19kHz PILOT position, Stereo Pilot injection level will automatically be switched and displayed on the bottom, highest sensitivity scale as shown by the scale indicator.

Stereo Pilot is measured through a narrow 19kHz bandpass filter. The measurement should be rock-solid, even with heavy program modulation. Any Pilot "bounce" in time with the music indicates a non-linearity somewhere in the transmission path. "Composite Clippers," thankfully passing out of vogue, are notorious for causing intermodulation between the Stereo Pilot and program audio. The only legitimate source of system nonlinearity would be multipath distortion of the off-air signal—and this has to be pretty bad to make the pilot "bounce"!

While monitoring the 19kHz PILOT on the CARRIER MODULATION bargraph, cycle the SELECT button **(14)** associated with the DEMOD METERING display to the 19kHz position. This also shows the pilot injection level, but in dB relative to 100% modulation, or ±75kHz deviation. 10%, or ±7.5kHz deviation, on the upper display corresponds to −20dB on the lower. A typical 9% (±6.75kHz dev.) injection level would read −21dB. It should be evident that the percentage or deviation display has greater resolution than the dB display, and should be used when setting the pilot injection.

**Multipath Demonstration**

Thus far we have assumed solid reception with neither the LOW SIGNAL nor the MULTIPATH indicators **(6)** lighting. Now let's change that and see what happens.

The local station you have tuned in should be holding its TOTAL MOD. at a reasonable value, somewhere between 100% and 110% (±75kHz and ±83kHz deviation), maximum. Make a mental note of the usual maximum deviations. Now, grab your antenna wire and purposely orient it so that the MULTIPATH warning light comes on. You can monitor MULTIPATH on the DEMOD METERING display **(13)** to watch the actual distortion increase. The MULTIPATH warning light is set to come on with very modest amounts of actual multipath distortion, about the amount which will cause a 1% or less error in the TOTAL MOD. reading. Somewhere above the point at which the light comes on, and certainly when the bargraph readout reaches mid-scale, the indicated TOTAL MOD. will increase *significantly*. You should be able to see this easily. With severe multipath distortion the TOTAL MOD. display may even go full-scale! Remember this demonstration and always make sure that multipath is at the absolute minimum before trusting *any* TOTAL MOD. measurement.

Here are some things to remember:

1. *NEVER* trust a carrier deviation (TOTAL MOD.) measurement if either the LOW SIGNAL or the MULTIPATH warning light **(6)** is on. This is not only for absolute measurements of your own signal, but for comparing modulation limits among stations in the immediate market as well.
2. Check the SYNTONY (tuning) indicator **(5)** from time to time, and fine-tune any preset which is not already dead-center as the STATION SELECT button **(3)** is *held down*.

3. Make it a habit to use the top, highest resolution scale for TOTAL MOD. measurements and when setting the Peak Flasher. The resolution on this range is 1%-per-step in the U.S. version 530-00, or 1kHz deviation-per-step in the 530-01 "EURO" version.

**DEMOD METERING Functions**

The displays **(13)** and their attendant buttons **(14** and **15)** are used in the measurement of audio frequency response, stereo separation, system crosstalk and noise, and for balancing channel drive to the Stereo Generator. Some proof-of-performance measurements are made with DE-EMPH **(7)** turned on, others with it turned off. The particular test or measurement will dictate how the 530 is set up and used.

These are things to remember:

1. DEMOD METERING is calibrated to read 0dB on the LEFT and RIGHT channel meters when the carrier is deviated to 100% (±75kHz) with a *monaural* signal. Because the Stereo Pilot accounts for almost 10% of total modulation in Stereo, full Left and Right channel *stereo* modulation will read −1dB.
2. DEMOD METERING has *quasi-peak response* on the normal, 0dB range, *averaging response* on the more sensitive range when 30dB additional GAIN **(15)** is switched in.
3. System Crosstalk measurements (main-to-sub and sub-to-main) are made by the stereo sum-and-difference method, with the 19kHz Stereo Pilot switched ON and deemphasis OFF. L+R and L−R measurements represent "main" and "sub," respectively.
4. Be aware of the limitations of stereo separation from an off-air signal. Refer to Figure 4 on Page 6.
5. Remember that MULTIPATH and SIGNAL LEVEL measurements are *relative measurements only,* and bear no relation to scale numbers.

**38kHz Residual Measurement**

Stereo-FM broadcasting transmits the L−R channel difference information as a double sideband, suppressed carrier signal. Historically, the DSB subcarrier was generated with analog multiplier circuits which had to be carefully balanced to fully suppress the 38kHz carrier frequency. Although nearly all modern FM Stereo Generators employ digital synthesis techniques for generating a composite baseband signal, with high inherent suppression of the 38kHz carrier, the U.S. FCC and regulatory agencies in other countries may still specify a maximum level for the 38kHz residual component in the absence of modulation. The 530 lets you measure this component, though you'll rarely ever find it.

Like the measurement of the 19kHz Stereo Pilot injection level, 38kHz residual is measured through a narrow bandpass filter. The 19kHz Stereo Pilot is carefully guarded by program low-pass filters in the Stereo Generator so that high frequency program components which approach, and could interfere with, the Pilot are eliminated. But the 38kHz DSB subcarrier frequency is *not* similarly protected. Very low program frequencies can generate legitimate sidebands very close to the 38kHz suppressed carrier.

This means that 38kHz residual must be measured *without program modulation.* With the program input to the Stereo Generator turned off, what the 530 measures as 38kHz residual (generally −50dB or below) is either carrier leakage or the second harmonic of the Pilot. If you check this measurement with program input applied, the meter will bounce around near −20dB in time to bass frequencies.

## SUBCARRIER (SCA AND RDS) INJECTION LEVEL MEASUREMENT

As already mentioned on Page 17, the Model 530 has no internal provision for *selectively* measuring the injection levels of SCA and/or RDS subcarriers in the presence of normal program modulation. This would require a sharp bandpass filter in the metering circuit, much like the ones for 19kHz Stereo Pilot and 38kHz residual measurements, but sharply tuned for each subcarrier frequency.

Subcarrier injection levels may be measured with good precision, however, if the program audio and Stereo Pilot can both be turned off during the injection adjustment. The following steps outline the procedure.

STEP 1 Turn *off* any subcarriers presently being broadcast.

STEP 2 Feed a source of "test" material into the program chain. Traditional pop music (with its limited dynamics) is an ideal test signal for this exercise. It is important that the peak limiting section of the Audio Processor is active during this procedure. If no peak reduction is indicated, advance the drive level to the peak processing circuitry to ensure full and dense modulation. (Don't worry, you can (and *should!*) back this down later.)

STEP 3 The Stereo Generator should now have Left and Right channel input signals corresponding to dense, 100% modulation. With the system in its normal (stereo) operating mode, set the Stereo Generator output level control so that the TOTAL MOD. reading on the 530 *consistently* peaks at 100% (±75kHz dev.). If a proper program source was selected, indicated CARRIER MODULATION should rarely fall below the 100% (±75kHz dev.) mark. The 530 should be at its highest resolution, on the uppermost metering scale.

STEP 4 Turn off the audio feed and switch the Stereo Generator to MONO to kill the 19kHz Stereo Pilot. Downrange the 530 TOTAL MOD. display to the 3% to 15%, or ±1kHz to ±12kHz deviation, range. No modulation should be evident.

STEP 5 Turn on the subcarrier generator. Set its output level for the required injection; nominally 10% (±7.5kHz dev.) for SCA and telemetry channels, 5% (±3.75kHz dev.) for RDS (RBDS) and some paging services. *Note the following important information* and then complete Steps 6, 7 and 8.

(IMPORTANT) Because the demodulated baseband (Composite) signal recovered from the off-air carrier does not have a perfectly flat frequency response, the following correction factors (derived from Figure 1, Page 5) should be used when setting subcarrier injection levels.

| SUBCARRIER FREQUENCY | DESIRED INJECTION | SET INJECTION TO INDICATE |
|---|---|---|
| 57kHz | 5% (±3.75kHz) | 5.0% (±3.75kHz) |
| 57kHz | 10% (±7.5kHz) | 9.75% (±7.25kHz) |
| 67kHz | 5% (±3.75kHz) | 4.75% (±3.5kHz) |
| 67kHz | 10% (±7.5kHz) | 9.5% (±7.0kHz) |
| 91kHz | 5% (±3.75kHz) | 4.5% (±3.5kHz) |
| 91kHz | 10% (±7.5kHz) | 9.0% (±6.75kHz) |

STEP 6 Repeat Step 5 for any other subcarrier signals. These must be done one-at-a-time, with all subcarriers off except for the one being adjusted.

STEP 7 Turn on any other subcarriers which have now been set. Restore the Stereo Generator to its STEREO mode and turn on the test program material per Step

2. With the 530 switched back to its highest resolution (top-most) scale, TOTAL MOD. should peak the same *percentage above 100%* (±75kHz dev.) as the percentage injection of the subcarrier, or the *sum* of the percentages if more than one subcarrier is transmitted.

STEP 8 Reduce the output of the Stereo Generator (composite stereo baseband signal only) so that the indicated TOTAL MOD. does not exceed the peak deviation permitted. In Europe this is generally limited to a maximum of ±75kHz deviation. Under current U.S. law, peak modulation may consistently reach 105% if one subcarrier is transmitted, or 110% if two or more subcarriers are in use. Touch-up the Stereo Generator (Composite) output level as required for desired TOTAL MOD. If readjustment amounts to more than a few percent, repeat these steps to ensure a proper ratio between subcarrier injection and total carrier deviation.

## THE COMPOSITE INPUT/OUTPUT

A switch and BNC connector on the back provide access to: 1) externally monitor the off-air composite baseband signal, and to: 2) route an external baseband signal directly into the Model 530.

**Composite Output**

When the switch is to the *right,* in the NORM/(OUT) position, the off-air baseband signal is available at the COMPOSITE IN/OUT jack. At 100% modulation (±75kHz deviation) the composite output is approximately 2 volts p-p from a 75-ohm resistive source. This may be coupled directly to the input of a spectrum analyzer for supplementary level measurement and signal analysis, or to an outboard subcarrier demodulator for RDS and SCA transmission injection measurement, decoding and monitoring. *The switch must remain in this position for normal 530 use.*

**Composite Input**

When the switch is moved to the *left,* to the EXT/(IN) position, the measurement and metering circuits of the 530 are disconnected from the FM receiver section. An external composite input may now be fed *into* the COMPOSITE IN/OUT jack, allowing measurements to be made directly from the baseband output of the Stereo Generator or STL receiver. The input has a high impedance (47k-ohm) input characteristic, and accepts a baseband signal of approximately 2 volts p-p, corresponding to 100% (±75kHz dev.) Total Modulation.

When the 530 is switched-over to monitor an external baseband input, the FM receiver section remains active, even though it is disconnected from the metering circuitry. This means that the LOW SIGNAL and MULTIPATH warning indicators and metering provision are still functional, but should be disregarded, since they do not pertain to the baseband signal which is fed-in directly.

## THE USER INTERFACE CONNECTOR

A 25-pin "D-Sub" connector on the Model 530 back panel brings-out a number of internal monitoring points, so that any measurement or alarm function may be duplicated at a remote location.

Figure 10 shows the rear-panel USER INTERFACE connector, as viewed from the back of the unit (looking directly into the connector). Mating (male) connectors are universally available because of their widespread use in computers. The tabulation following Figure 10 gives the pinout, the functions, signal levels and related particulars, and suggested uses for the various circuit points provided.

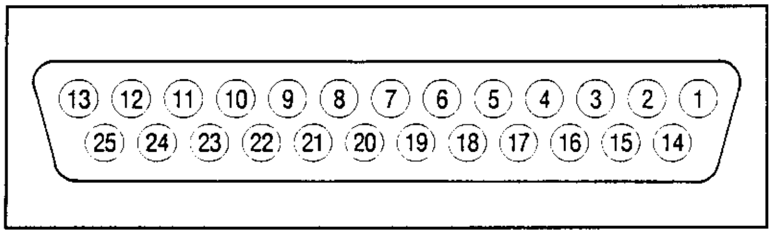



**Figure 10** - USER INTERFACE Connector

| CONNECTOR PIN NO. | MONITORING FUNCTION | REMARKS |
|---|---|---|
| 1 | +9VDC | The internal positive 9-volt regulated power supply. This source is made available to operate remote LED displays, alarm relays, etc. Total current consumption from this supply should not exceed 50ma. |
| 2 | −9VDC | The internal negative 9-volt regulated power supply for remote LED indicators, etc. Total current consumption should not exceed 50ma. |
| 3, 4, 5 | GROUND | This is a chassis (circuit) ground for signal output reference/return, etc. |
| 6 | PEAK FLASHER | Logic output for a remote Peak Flasher. This line normally sits near −9 volts, and goes to +9 volts whenever the front-panel PK indicator lights. This line should work against the −9-volt supply (pin 2) to drive a remote LED with a 2.2k-ohm series resistor. |
| 7 | MULTIPATH LEVEL | A DC voltage proportional to the relative amount of multipath distortion in the received signal. 5 volts corresponds to a full-scale indication on the front-panel meter, and 0.5 volts or less to an "acceptable" amount of multipath. This can be read-out on a remote voltmeter for aiming a directional antenna. |
| 8 | UPPER DEMOD METER | A 0−5-volt output proportional to the *upper* DEMOD METERING bargraph display, following whatever function (and gain) is locally selected for front-panel metering. LEFT, L+R and 19kHz Stereo Pilot measurements *are dB-linear.* 5VDC corresponds to the +10dB panel scale marking, 4VDC to the 0dB reference, 3VDC to the −10dB point, etc. The GAIN button will affect voltage scaling just as it does the panel metering. |
| 9 | LOWER DEMOD METERING | Exactly as just described for pin 8, but for the *lower* DEMOD METERING bargraph display. |

| | | |
|---|---|---|
| 10 | DEAD AIR ALARM | This logic line normally sits at −9VDC, toggling to +9VDC after *modulation* (program audio) has been lost for 10 to 15 seconds. This can work against −9VDC (pin 2) to light an LED or operate another type of remote alarm with an appropriate series resistor to limit current to 5ma. |
| 11 | TOTAL-MOD METERING | A 0−5-volt output proportional to the CARRIER MODULATION bargraph display, following whatever function is locally selected for the front-panel meter. 3.5VDC corresponds to 100% carrier modulation, or ±75kHz carrier deviation. When the 3% to 15% (±1kHz to ±12kHz dev.) scale is selected, 3.5VDC corresponds to 10% carrier modulation, or ±7.5kHz deviation. Other voltage values are directly proportional to the scaling, with zero-volts equal to an unmodulated carrier. |
| 12 | CARRIER LOSS ALARM | This point sits at +9VDC when a valid carrier is tuned, and swings to −9VDC when the LOW SIGNAL panel indicator lights. This line can work against +9VDC (pin 1) to light a remote LED when carrier is lost. Output current should be limited to 5ma. |
| 13 | PILOT LEVEL | A 0−5-volt output directly proportional to the injection level of the 19kHz Stereo Pilot. 3.5VDC corresponds to 10% (±7.5kHz dev.) injection. |
| 20 | LEFT BALANCED OUTPUT + | The "high" side of the Left program channel, 600-ohm balanced line output. |
| 21 | LEFT BALANCED OUTPUT − | The "low" side of the Left program channel, 600-ohm balanced line output. (<u>Not to be grounded</u> if the "high" side is used for an *un*balanced output.) |
| 22, 23 | SHIELD GROUNDS | Chassis ground for the shields of the Left and Right channel balanced line outputs. |
| 24 | RIGHT BALANCED OUTPUT + | The "high" side of the Right program channel, 600-ohm balanced line output. |
| 25 | RIGHT BALANCED OUTPUT − | The "low" side of the Right program channel, 600-ohm balanced line output. (<u>Not to be grounded</u> if the "high" side is used for an *un*balanced output.) |

## IMPORTANT USE DISCUSSIONS AND CAUTIONS

The Model 530 will give valid and repeatable measurements of normal, "real-world" broadcast signals typically encountered in common broadcasting practice. It is nonetheless possible to "confuse" the 530, causing it to give readings which seem erroneous. For this reason it is important to know the limitations of the 530 so that measurement pitfalls may be understood and avoided.

**Poor Reception Conditions**

Cautions about measurement errors from insufficient signal strength and from effects of multipath distortion have already been covered, ad nauseam. Sufficient to say that *readings will not be accurate* if either the LOW SIGNAL or the MULTIPATH warning indicator is lighted.

**Reception Bandwidth and Adjacent Station Rejection**

Designed for local-market coverage, the 530 was never meant to win DX awards. To maintain a linear passband frequency and phase response, RF, IF and baseband filtering in the composite signal path of the 530 is necessarily very wide and not very steep (see Figures 1 and 2 on Page 5). This means that rejection of first- and even second-adjacent station carriers is limited, and can compromise the accuracy of Total Modulation readings *if the tuned signal is not significantly stronger than its adjacents.*

One way to verify that an adjacent signal is influencing your Total Modulation reading is to selectively monitor positive and negative carrier deviations. In most cases carrier deviation will be symmetrical; that is, POS. DEV. and NEG. DEV. will measure the same as TOTAL MOD. on the bargraph display. Exceptions to this rule include lightly processed speech waveforms, which can be highly asymmetrical, or gross malfunctions within the stations's audio processor or exciter; either problem usually otherwise evident.

If the 530 shows a marked difference in the independent deviation measurements, much higher POS. DEV. than NEG. DEV., for instance, check for a strong first- or second-adjacent signal above your own. In such a case it should be possible to tune the offending station on a portable radio and watch your *own* modulation bounce in time to *their* music! The only way around this problem is to improve the strength of your carrier with respect to the interfering one; a directional antenna or, to make absolutely certain, a direct connection to the transmitter antenna matching network.

Once the presence of an interfering signal is verified, and *proven* to influence *only one deviation polarity,* the *opposite* polarity measurement can be used (with obvious caution) in lieu of a true TOTAL MOD. reading.

**Tuning Errors**

Accurate Total Modulation measurements require the incoming signal to be precisely centered in the RF/IF passband. The 530 employs AFC to correct for modest amounts of drift; nevertheless, the center, green SYNTONY tuning indicator LED should be the only one lit when a STATION SELECT button is held down. Holding-down the button temporarily defeats the AFC so that the uncorrected (open-loop) error can be seen and eliminated. Station memories should be carefully fine-tuned once the 530 is installed and at its nominal operating temperature. It is also a good idea to routinely check the tuning accuracy, touching-up if need be.

**AM Noise Measurement Precluded**

Despite the broadband nature of the Model 530 receiver, its finite IF bandwidth invariably limits it for some measurements. The fact that this is a tuned system at all rules out the measurement of synchronous AM noise, since even a 0.1dB amplitude droop at the band edges would limit measurements to −40dB.

**Demodulation Nonlinearity**

Most routine measurements are not significantly compromised by less-than-ideal IF amplitude and phase responses. Off-air stereo separation, for instance, is degraded only about 10dB over the figure obtained from a Composite, baseband input. But at 40dB or better, over most of the audible range, it remains adequate for routine, off-air measurements. Nevertheless, as the modulating frequency increases, IF bandwidth limitations become more of a factor.

If the FM carrier were purposely modulated to 100% at 50kHz or above, IF passband limitations of the Model 530 would be apparent. The recovered waveform would show significant distortion, and IF filter asymmetry would cause the 530 to display unequal positive and negative carrier deviations.

Fortunately, this is not a real-world situation. The spectral profile of an FM broadcast is, by nature, skewed toward the lower frequencies. Monaural transmissions have *no* energy above 15kHz, and a worst-case stereo signal with full L−R modulation at 15kHz forces the upper suppressed-carrier sideband to just under 50% modulation at 53kHz. Additional subcarriers (RDS or SCA) can modulate the carrier up to 100kHz, but at very low injection (modulation) levels. With a typical stereo program modulating the transmitter to 100%, the 10% injection of an additional subcarrier, even at 91kHz, will remain well within the linear passband of the IF and add correctly to the Total Modulation measurement.

**Gross Overmodulation**

The 530 assumes that 100% modulation corresponds to the accepted worldwide standard of ±75kHz carrier deviation. Alas, in some countries standards either are not recognized, or official agencies make enforcement a very low priority.

The 530 demodulator has good linearity out to 150% modulation, or to about ±115kHz carrier deviation. Although it might be possible to recalibrate the unit, referencing 100% modulation to a deviation greater than ±75kHz, this would most surely tax the IF and detector linearity and result in unacceptably inaccurate Total Modulation measurements.

# Section IV

# CIRCUIT DESCRIPTIONS
# AND
# CALIBRATION NOTES

Model 530 circuitry described in this section references the three pages of schematic diagrams found in the Appendix, Section V.

## COMPONENT DESIGNATION SYSTEM

Inovonics had adopted a convention for designating components which may differ from what you're used to. Many equipment manufacturers will assign component reference designations in a methodical manner on the schematic diagram. This is fine for walking an electronics class through the circuitry, because Q1 will feed Q2 through C1, with R1 terminating the input, etc. But when you try to locate the physical component on the circuit board, it may take a while to spot that elusive R6, smack-dab in the center of the board between R67 and R103.

What we do, instead, is to sequentially number the actual components, beginning in the upper-left-hand corner of the circuit board and working down one neat, even row, jumping up to the top of the next row and so-on, with the highest numbered components found at the bottom-right-hand corner.

## RF / IF / DETECTOR SECTION (Schematic Sheet 1)

**Front-End Module** A commercially-available FM "front-end" module was chosen for its superior stability, bandwidth, tracking and dynamic performance. It contains a varactor-tuned RF amplifier, local oscillator and mixer circuitry. The dense, critical internal layout of this module relegates its servicing to complete replacement in the unlikely event of its failure.

**Input Switching** The 530 is provided with two RF inputs: J606, the normal "F" connector antenna input, and J605, a padded "BNC" input for directly-coupled, high-level RF samples. These are selected with two reed relays, K2 and K1, respectively. When STATION SELECT #1 is engaged, positive DC logic from the front panel subassembly is fed to IC61A through R254. With jumper JMP4 in the "BNC" position, this will force the output of IC61A high, bringing up K1 and selecting the high-level input. Jumpering JMP4 for "F" keeps K2 closed for an antenna input in all STATION SELECT positions.

**IF/Detector Circuit**

The 10.7MHz IF amplifier and quadrature detector functions are incorporated in IC59 and its associated components. This particular integrated circuit, the National Semiconductor LM1865, is considerably advanced over similar ICs found in consumer receivers. It employs proprietary distortion-reducing techniques which extend demodulation accuracy and linearity beyond the usual range for this topology.

AGC internal to the LM1865 yields a voltage proportional to the strength of the incoming signal. This is used for the alternate front-panel SIGNAL LEVEL display. and comparator IC60A monitors this voltage to give the front-panel and remote LOW SIGNAL alarms.

The baseband signal recovered by IC59 is buffered by emitter-follower Q12 and fed to the Composite low-pass filter and equalizer comprising IC54 and IC55. The passive low-pass function reduces out-of-band noise and signal components. R206 is adjusted for flattest response below 100kHz, R210 for best passband phase response. The effect of this filter, in addition to IF passband characteristics, accounts for the baseband response shown in Figures 1 and 2 on Page 5.

IC23 sets the gain of the Composite signal to the peak rectifiers for CARRIER MODULATION display. IC23A switches-in an additional 20dB gain for the lowest scale range. IC54A is a DC servo stage establishing a quiescent operating point for all circuitry between the quadrature detector and the peak rectifiers. Servo action extends the low frequency response to DC, necessary for accurate measurement of complex program waveforms.

**Composite IN/OUT**

With rear-panel switch S601 in its normal OUT position, an equalized and phase-corrected off-air baseband signal with 75-ohm source impedance appears at the COMPOSITE IN/OUT jack, J604. When the switch is moved to the IN position, this same jack accepts an external baseband input for measurement and display. In the IN position, R223 supplies the DC bias normally provided by the quadrature detector.

## RECEIVER TUNING (Schematic Sheet 1)

**DC Tuning Voltage**

The eight multiturn tuning potentiometers, R272 to R279, bridge a zener-stabilized negative DC voltage source buffered by IC63B. A binary address from front-panel STATION SELECT logic selects the corresponding tuning voltage through analog multiplexer IC64. IC63A inverts and re-scales the tuning voltage to drive the TOTAL MODULATION bargraph display in its frequency readout mode.

"Raw" tuning voltage from IC64 is also fed to inverting amplifier stage IC61B through R269 and R267. R269 is bridged by temperature-compensating diode CR29 for thermal correction. IC61B inverts and re-scales the tuning voltage for the varactor elements within the front-end module.

C125 is normally maintained in parallel with R266 through analog switch section IC62A. The resulting integration around IC61B eliminates noise in the tuning voltage which would appear in the demodulated program signal. To make tuning virtually instantaneous, however, C125 is switched out whenever any STATION SELECT button depressed. R270 and C127 delay the return of integration once the STATION SELECT button is released; this gives C125 a chance to charge to the new value before returning to the circuit.

**Automatic Frequency Control (AFC)**

When the quadrature detector is perfectly balanced; that is, when the received carrier is in the center of the RF/IF passband, no current flows through R259. Thus IC60B, a differential amplifier monitoring the voltage drop across R259, has a zero output voltage when the station is correctly tuned. The output of IC60B directly controls the three SYNTONY tuning LEDs on the front panel subassembly.

Any tuning error results in an output from IC60B. This is summed with the "raw" tuning voltage by IC61B to furnish AFC action, keeping the received carrier centered in the RF/IF passband. IC62B, switched by logic from the front-panel assembly, opens the AFC loop whenever a STATION SELECT button is *held down.* AFC is defeated so as not to "fight" the manual tuning procedure. This also gives maximum sensitivity of the SYNTONY tuning indicator.

## CARRIER MODULATION MEASUREMENT (Schematic Sheet 1)

**Peak Rectifier**

The off-air or externally injected baseband signal appearing at the output of IC23A is also inverted by IC25A. This creates positive-going waveforms for both positive and negative carrier deviations. Analog switch sections IC24B and IC24A pass these positive-going excursions corresponding to POS. DEV. and NEG. DEV., respectively; both are on for TOTAL MOD.

Q5, Q6, Q7 and Q8 comprise a unity-gain differential-input amplifier. The utility of discrete components here is two-fold: 1) the amplifier can be arranged to have two, isolated non-inverting inputs, and: 2) the output characteristic can be non-symmetrical; that is, a rapid, "stiff" positive output excursion and a slow, R/C return to zero. This circuit constitutes the peak rectifier, the *instantaneous* peak value temporarily held by C33.

**Peak Integration and Peak-Hold Function**

IC25B buffers the rectifier output to charge the primary integrating capacitor, C32, through a resistor chosen at JMP1 for the desired peak integration characteristic. IC26A buffers the integrated value, passing it to the CARRIER MODULATION metering circuitry. C32 normally discharges through R62, this time constant shaping the metering fallback characteristic. In order to accurately measure very fast peaks the bargraph fallback is delayed for a fraction of a second. Whenever a new peak value exceeds the present one, comparator IC26B toggles, driving Q2 into saturation and quickly discharging C23. As C32 charges completely to the updated peak value, IC26B toggles back, turning off Q2 and allowing C23 to charge through R63 and R64. A fraction of a second into this charge cycle, Q1 will saturate and the bargraph will start to descend.

## 19kHz STEREO PILOT AND 38kHz RESIDUAL FILTERS (Schematic Sheet 1)

**Initial Filtering**

The baseband signal is presented to two, first-order band-pass filters: IC33B, tuned to 19kHz; and IC33A, tuned to 38kHz. Though the "Q" of these tuned amplifier stages is formidable, the passband selectivity is insufficient to enable accurate measurement of the 19kHz and 38kHz components. These stages simply pre-condition the signal, reducing the amplitude of the higher-level program audio.

**"Digital" Filtering**

Y1 is a U.S. television color burst crystal oscillating with IC19 at 3.58MHz. This is divided by IC20, IC21 and IC22 to yield two clock frequencies: 38.08kHz and 19.04kHz. These are fed to SPDT analog switch sections IC34C and IC34A, respectively. These switch sections, along with following integrating differential amplifiers, IC35A and IC35B, form double-balanced modulators, the output of which is the difference frequency between that of the baseband component and the clock; in other words, 80Hz and 40Hz, corresponding to Stereo Subcarrier and Stereo Pilot. The 80Hz derivative of the 38kHz subcarrier is low-pass filtered by IC36A, the 40Hz derivative of the Stereo Pilot by IC36A. In each case an easily-obtained low-pass function is translated directly to a band-pass filter characteristic, the derived low-frequency waveform corresponding in amplitude to the original frequency.

The waveform recovered by IC36A, representing the level of the Stereo Subcarrier, is fed directly to the appropriate metering circuit. The output of IC36B, representing the 19kHz Stereo Pilot level, is full-wave-rectified by IC37B and IC38B. IC38A, IC34B and IC37A comprise a "synchronous peak detector" which provides an absolute DC peak value of the 40Hz waveform. The merit of this filtering technique is the negligible ripple in the recovered DC, less the attendant long filtering time constant usually necessary at low frequencies. This DC level is routed to the Stereo Pilot metering circuit and to the Multipath Detector.

**Multipath Detector**

The Inovonics 530 measures and qualifies multipath distortion by monitoring the *amplitude perturbations* of the 19kHz Stereo Pilot. The DC level recovered from the Stereo Pilot synchronous rectifier is AC-coupled to full-wave averaging rectifier IC39 and its associated components. Thus the output of IC39B is zero for a rock-solid Stereo Pilot, but any envelope (amplitude) modulation of the 19kHz Pilot will result in a proportional DC output voltage. This measurement is fed to the appropriate metering circuit for MULTIPATH display, and to comparator IC53B which lights the front-panel MULTIPATH alarm LED.

## CARRIER MODULATION DISPLAY OPTIONS (Schematic Sheet 1)

**Display Selection**

IC18 is a 1-of-8 analog multiplexer which routes a selected measurement to the CARRIER MODULATION display driver on the front panel assembly. Primary control of IC18 is by IC29, a 2-bit binary counter which may be cycled by the front-panel SELECT button through the TOTAL MOD., POS. DEV., NEG. DEV. and 19kHz PILOT display options. IC30A decodes this same logic to light a corresponding LED indicator. Selection logic is overridden when the SET PK button is held down, allowing the trip level of the Peak Flasher to be read on the CARRIER MODULATION display.

**Scale (Range) Selection**

The CARRIER MODULATION display of the Inovonics 530 has two deviation display ranges: a "high resolution" range for normal monitoring, and a much broader, "expanded" range. The actual signal level fed to the display driver circuitry is the same in both cases; range change is effected by altering the voltage reference at each end of the voltage comparator resistive divider network internal to the bargraph display drivers. The various reference levels are selected by IC51A, for the top of the scale, and by IC51B for the bottom. Because this scaling circuitry is common to DEMOD METERING as well, please also refer to the additional explanation which follows the Circuit Description of the front-panel assembly display driver.

## PEAK FLASHER (Schematic Sheet 1)

Comparator IC32A has one input connected directly to the CARRIER MODULATION peak rectifier at the output of buffer stage IC26A. The other input is fed a DC voltage adjusted by a potentiometer accessed through a hole in the front panel directly below the SET PK button. IC18 routes the potentiometer voltage directly to the CARRIER MODULATION bargraph display when the SET PK button is *held down*. This allows the user to calibrate the voltage to a "flash value" which corresponds precisely to a desired level of carrier deviation. Once the DC voltage is adjusted, the SET PK button is released and the bargraph reverts to its carrier modulation display function.

Whenever the instantaneous deviation reaches the preset DC value, the output of IC32A toggles positive. This charges C35 through CR19, taking the output of IC32B to the positive rail and lighting the front-panel PK indicator. C35 discharges slowly through R92, stretching the flash duration to ensure an adequate display of even the briefest modulation peak.

## STEREO DECODER AND PROGRAM LOW-PASS FILTERS (Schematic Sheet 2)

**Stereo Decoder**

One of the better integrated-circuit Stereo Decoders was chosen for service in the Model 530. This IC, the Signetics TDA 1578, is typically capable of 50dB stereo separation. By including some outboard circuitry suggested by Signetics engineers, this becomes a guaranteed figure for direct baseband inputs. Off-air performance is limited entirely by the RF/IF passband response. (See Figures 3 and 4 on Page 6.)

Composite baseband, whether an equalized, phase-corrected off-air signal, or a directly-coupled input from a Stereo Generator or STL, is AC-coupled to the Stereo Decoder, IC57. The separately-regulated negative power supply to this IC, as well as the various R/C networks which surround it, all help to optimize the stereo separation performance of this IC.

**De-Emphasis**

De-emphasis logic from the front panel assembly controls analog switch sections IC56C and IC56D. With the front-panel DE-EMPH. button normally engaged, these connect a parallel load capacitance to provide either 50$\mu$s or 75$\mu$s de-emphasis, as jumpered at JMP2 and JMP3.

**Program Low-Pass Filters and Line Outputs**

The Left and Right Channel outputs of the Stereo Decoder feed 7-pole, active-elliptic low-pass filters. Amplitude response of these filters is ±0.5dB to 16kHz, and rejection at 19kHz and above is 60dB or more. IC44 buffers the filter outputs and brings the program signal level to 0dBu for the unbalanced LEFT and RIGHT OUTPUT jacks. IC43 inverts each channel to provide the opposite phase for the 600-ohm, balanced Line Output available at the USER INTERFACE connector.

## DEMOD METERING RECTIFIERS AND LOG CONVERSION (Schematic Sheet 2)

**Sum and Difference Matrix and Switching**

IC6A sums the Left and the Right program channels for the L+R measurement; differential stage IC6B yields the L−R stereo difference. Analog switch section IC7B routes L, L+R, or the down-converted 19kHz PILOT to the upper DEMOD METERING display rectifier, IC78 similarly sends R, L−R, or the converted 38kHz subcarrier residual to the other rectifier. These analog switch sections are controlled by IC4, a 2-bit binary counter cycled by the front-panel SELECT button. IC5A decodes the binary address to light a corresponding indicator LED and, on the fourth count, to also inject MULTIPATH and SIGNAL LEVEL information downstream of the rectifiers.

**Rectifiers**

IC9 drives the DEMOD METERING rectifiers, IC8 switching-in an additional 30dB gain when the front-panel GAIN button is engaged. IC10, IC11 and IC12 comprise full-wave, absolute-value rectifiers. With normal gain, IC13 shunts R21 and R44, and the rectifier has a "fast peak" response established by the R23/C14 and R46/C19 time constants. When the additional 30dB gain is switched in, R21 and R44 provide "averaging" response for a more stable display of low level signals close to the noise floor.

**Log Converter**

IC28A is a free-running astable multivibrator oscillating at approximately 100Hz. Each time the output toggles to the positive rail, C24 and C34 are quickly charged to about +7 volts. When the output of IC28A goes negative, C24 discharges toward ground with a *linear* ramp through constant-current source Q3. Concurrently, C34 discharges toward ground through R88 and R90 with an R/C *log* ramp. The log ramp, buffered by IC28B, is presented to one input of the IC14 comparator pair, the rectified signal voltage to the other comparator inputs. When the *log* ramp falls to the exact value of the rectified signal, IC14 triggers one-shot multivibrator IC15. A narrow output pulse from IC15 momentarily closes analog switch IC40, charging C51 and C50 to the value of the *linear* ramp at that same instant. This sampled value is held by buffer amplifier IC41. Thus the *log* value of the rectified signal is converted to the *linear-dB* scaling of the DEMOD METERING bargraph display.

IC42, controlled by the fourth state of binary counter IC4, routes the DC voltages corresponding to MULTIPATH and SIGNAL LEVEL directly to the display drivers.

## DISPLAY DRIVERS (Schematic Sheet 3)

**Multiplexed Displays**

The CARRIER MODULATION and DEMOD METERING displays are 50-element LED bargraphs, each actually incorporating five, 10-segment LED modules stacked end-to-end. The three bargraph displays share a common group of five LM3914 bargraph display driver ICs.

Considering the three displays as three *rows* of fifty *columns,* LED cathodes are paralleled in each *column,* anodes paralleled in each *row.* Resistive ladder networks associated with the level comparators internal to each LM3914 are series-connected to produce a single, 50-step bargraph driver array.

Multivibrator IC508B free-runs at approximately 300Hz, clocking 3-state counter IC507. Analog switch sections IC506D, IC506B and IC506A sequentially apply the three signals for display to the bargraph driver IC inputs, while V-FETs Q501, Q502 and Q503 apply power to the corresponding LED rows.

**Scale Logic**

Referring back to Schematic Sheet 1, a group of reference voltages is presented to the various inputs of analog multiplexers IC51A and IC51B. The selected values are the comparator reference voltages for the top and bottom of the bargraph displays, respectively, and are buffered by IC52B and IC52A. Logic for this selection is a composite of: 1) display multiplexing logic, and: 2) selected CARRIER MODULATION display resolution.

IC16 is a 2-bit binary counter cycled by the front-panel SCALE button. IC17A decodes the output of IC16 and lights a SCALE indicator to show which range is selected. IC17A also controls IC51A and IC51B for appropriate CARRIER MODULATION display scaling, and introduces 20dB gain in IC23A for the lowest display range.

## FRONT PANEL SUBASSEMBLY (Schematic Sheet 3)

Aside from the multiplexed bargraph display driver section already discussed, front-panel subassembly circuitry is largely passive. Included in this category are pushbutton switches and LED indicators which either control, or are controlled by, logic circuits on the main board.

**Op-Amp Flip-Flops**

IC508A, IC509B and IC509A are conventional analog op-amps connected in a bistable flip-flop configuration for the alternate-action pushbutton GAIN, DE-EMPH. and (forced) MONO switches. This somewhat unusual circuit performs switch debouncing as part of the push-on/push-off function. Q504 and the associated components provide a power-on reset for the three flip-flops, as well as for the STATION SELECT logic.

**STATION SELECT Logic**

IC512 encodes the 1-of-8 STATION SELECT button logic into a binary code which is latched by IC510. The binary logic is: 1) decoded by IC511 to light the appropriate STATION SELECT indicator LED, and: 2) routed to the analog multiplexer associated with the DC tuning voltage.

Q504 resets IC512 to STATION SELECT position #1 when power is first applied. A logic command from IC512 is also fed to the main board when any button is held down. This defeats AFC and switches the CARRIER MODULATION display to its frequency readout mode for station tuning.

## POWER SUPPLIES (Schematic Sheet 1)

Two "three-terminal" linear voltage regulators, IC1 and IC2, deliver the positive and negative 9-volt supplies for all analog and CMOS digital circuitry. A step-down switchmode regulator, IC3, delivers +5 volts at high current for the multiplexed LED bargraph displays.

# GENERAL CALIBRATION CONSIDERATIONS AND GUIDELINES

**Calibration Accuracy Requirements**

The Inovonics 530 is intended as the broadcaster's primary indicator of carrier modulation, or deviation. Clearly, any piece of equipment entrusted to yield such implied high accuracy requires very careful calibration, and the use of calibration equipment and standards which, themselves, have a minimum of *five times* the intended accuracy of the calibrated unit.

First-class components are used throughout the Model 530, and circuitry was specifically configured to mitigate drift and measurement inaccuracies over the long-term. There is no particular requirement for "routine calibration" of the 530, though 24 months is considered a proper interim for performance verification of modulation monitoring equipment. *It is resolutely recommended* that any repair and recalibration of the equipment be referred to the factory, where specialized, efficient procedures and equipment with the necessary accuracy will assure prompt service and, thus, the best *maintenance value.*

We nonetheless concede that return to the factory may not always be possible under field maintenance circumstances. Calibration of the 530 by the user is not only discouraged, but a complete and foolproof *Calibration Procedure* is beyond the scope of this Manual. In place of a detailed procedure, we present an accurate description of: 1) the *function* of each calibration adjustment, and: 2) the *desired effect* of proper adjustment in each case.

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**PLEASE BE ADVISED AND FOREWARNED** that field calibration of the Inovonics 530 by guidelines described in this Manual cannot guarantee the measurement accuracy stated in the product specification.

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**Circuitry Division**

Calibration of the 530 is divided into two parts, roughly broken at the COMPOSITE IN/OUT connector on the rear panel: 1) the stereo decoding and metering section, and: 2) the RF/IF and detector section.

Stereo decoding and metering circuitry is the more easily adjusted of the two sections, utilizing more common test equipment and familiar adjustment practices. On the other hand, RF/IF/detector section alignment is far more critical and requires sophisticated test gear. Also, slight misadjustments in this section can have complex, obscure effects over overall modulation measurement accuracy.

The final adjustment, that of setting the 100%-modulation level, requires a precisely-modulated carrier with ±75kHz deviation, verified with accurate Bessel-null procedures.

**Equipment Required**

A. **Sine/Square Audio Generator** with 10dB/step coarse attenuator and vernier; LEADER LAG-120A or equivalent.

B. **AC R.M.S. Voltmeter** with dBu scaling (0dBu=0.775V); LEADER LMV-181A or equivalent.

NOTE: A and B, above, represent an absolute *minimum requirement* for this equipment. A much better alternative is one of the "unitized" audio test sets, similar to the AUDIO PRECISION "PORTABLE-ONE PLUS," with digital frequency and level readouts.

C. **Oscilloscope,** 60MHz (minimum) Dual-Trace with two 10X (low-capacitance) probes.

D. **Spectrum Analyzer** with a stable, high resolution display of signals in the 100Hz to 100kHz range. Tektronics 7L5 or equivalent.

E. **Laboratory-Grade Stereo Test Generator** with a composite baseband output as well as an internal frequency-agile (synthesized) RF modulator for the FM broadcast band. This must include an internal, high-grade stereo encoder, a separate broadband input to the RF modulator, and a fairly accurate readout of percentage carrier modulation, or deviation. The internal RF modulator should have a calibrated coarse and fine output attenuator calibrated in dBf.

**Rotation of Calibration Adjustments**

As of this writing, Inovonics purchases single-turn trimming potentiometers from two sources and uses them interchangeably. *Beckman* pots are round, and the gray-colored, gear-like top may be engaged by a small screwdriver. *Tocos* pots are square and blue with a small white adjusting screw-slot in the center. There is one major difference between these trim controls: *their rotations are opposite.* This means that if we were to say, "turn R23 clockwise . . . ," it would hold true for one brand but not for the other. We have thus endeavored to refrain from calling out rotation direction.

**Meter Levels and Linearity**

With the rear-panel COMPOSITE IN/OUT switch in the IN position, and with a 400Hz, 0dBu sinewave applied to the COMPOSITE IN/OUT jack, R226 is adjusted for a TOTAL MODULATION display of 100% (or ±75kHz deviation) on the top, highest resolution scale.

At the same time, R144 and R173 are set so that Left and Right DEMOD METERING displays read 0dB. When the 400Hz test signal is reduced by exactly 30dB, R90 is adjusted so that both bargraph displays indicate −30dB. With the oscillator level returned to 0dBu, R144 and R173 may be touched-up for 0dB readings.

After the DEMOD METERING adjustments have been made, and with the 400Hz test signal at 0dBu, R226 may be touched-up so that TOTAL MODULATION reads 100% (or ±75kHz dev.) on the top scale.

**19kHz Pilot Metering**

The test signal applied to the COMPOSITE IN/OUT jack is reset to precisely 19kHz, level verified at 0dB. The CARRIER MODULATION display should read 100% (±75kHz deviation).

When the 19kHz test signal is downranged by exactly 20dB, and CARRIER MODULATION display scaling switched to the most sensitive scale, the reading should be 10% (±7.5kHz dev.). R131 is adjusted for this same reading when the SELECT button is cycled to the 19kHz PILOT measurement function.

**19kHz and 38kHz dB-Scale Metering**

Under the conditions just described, R34 is set for a −20dB reading on the upper DEMOD METERING scale when that function is switched to 19kHz/38kHz measurement. By increasing the frequency of the test signal to precisely 38kHz (still at −20dB), R35 may be adjusted for a lower DEMOD METERING scale reading of −20dB.

**L/R Balance**

The calibrated Stereo Test Generator is used to apply a Composite (stereo baseband) input, L+R modulated at 400Hz, to the 530 COMPOSITE IN/OUT jack at a level which indicates 100% (±75kHz dev.) CARRIER MODULATION on the 530 front-panel display. The test generator *must not* impart transmission pre-emphasis to the signal, and the Stereo Pilot level should be set for 10% injection. With DE-EMPH turned off and DEMOD METERING switched to read L+R and L−R, R144 is adjusted to balance the Left and Right Channel *amplitude* response as indicated by a null in the L−R reading. The GAIN button may be used to maximize display resolution.

At a modulating frequency of 15kHz, R194 is set to equalize *phase* response in the low-pass filters, again as evidenced by a null in the L−R reading.

With a 400Hz L−R Stereo Test Generator input, R11 is set for an L+R null.

With DEMOD METERING switched to LEFT and RIGHT, the two bargraph displays should register −1dB. R12 is set so that both displays dither equally between −1dB and 0dB once the actual level of the Stereo Test Generator is increased by about 0.5dB, as evidenced by the CARRIER MODULATION display reading about 105% (±79kHz dev.). This should hold true with either L+R or L−R modulation applied.

The foregoing steps should be repeated until you are sure that all adjustments are spot-on.

**Stereo Separation**

The baseband low-pass filter equalization trimmer, R206, and the Stereo Decoder PLL adjustment, R224, are adjusted in tandem for best stereo separation with the Stereo Test Generator signal applied directly to the COMPOSITE IN/OUT jack. These two pots are interactive, and are adjusted (with great tedium!) for greatest separation, consistent with the best separation symmetry, L-into-R and R-into-L, both at 400Hz and at 15kHz. You may find that what appears to be the optimum setting of R224 will not allow the Stereo Decoder to re-acquire lock when the Stereo Pilot is interrupted. If this is the case, an alternate setting of R224 (and R206) must be found.

**Detector Tuning**

Adjustments to the baseband detector section are made with a mid-band RF input to the ANTENNA input of the 530. The rear-panel COMPOSITE IN/OUT switch must be in the OUT (NORM) position. At 98.1MHz, the Stereo Test Generator RF output is set for a SIGNAL LEVEL reading at the top of the NORMAL range on the lower DEMOD METERING scale. A Spectrum Analyzer monitors the COMPOSITE IN/OUT jack.

The Sine/Square Audio Generator is fed directly to the broadband modulation input of the Stereo Test Generator. The test signal is a 10kHz squarewave at a level which deviates the Stereo Test Generator to approximately 100% (±75kHz dev.) modulation.

Any STATION SELECT position may be used. Using a 10:1 probe, the 'scope may be used to monitor the 10.7MHz IF at the right-hand end of R244. *While holding the* STATION SELECT *button down,* the corresponding front-panel tuning control is roughed-in to the incoming carrier, tuning first for maximum IF amplitude, then retuning for minimum envelope (amplitude) modulation. (In other words, the IF envelope is set for a constant amplitude for both the positive and negative deviation extremes, corresponding to the positive and negative excursions of the 10kHz squarewave test signal.)

Next, the quadrature coil, L6, is carefully and gently tuned *while holding the* STATION SELECT *button down,* for full brilliance of the central green SYNTONY indicator, with neither red LED indicator lighted. At this point the incoming signal is roughly tuned to the center of the RF/IF passband.

The STATION SELECT control now fine-tunes the 98.1MHz signal from the Stereo Test Generator for minimum *even-order* harmonic distortion of the 10kHz squarewave, *while keeping the* STATION SELECT *button depressed*. Once this is done, L6 is fine-tuned, again *while holding the* STATION SELECT *button down,* and again for best SYNTONY indicator balance. Repeat this Detector Tuning procedure until SYNTONY balance corresponds with minimum even-order distortion. Oh, yes; once this is finished you may release the button!

**Passband Phase Adjustment**

Under the foregoing conditions, the 530 will indicate a level of modulation higher than 100% (±75kHz dev.). The 10kHz squarewave from the Audio Generator should now be reduced in amplitude for a CARRIER MODULATION reading of about 100% (±75kHz dev.). R210, the baseband low-pass filter phase equalizer, is then set for a null (minimum reading) in the CARRIER MODULATION display reading.

**CARRIER MODULATION Calibration**

The 530, tuned to the Stereo Test Generator at 98.1MHz, is ready to be adjusted to indicate absolute total carrier modulation (deviation). Precision of this adjustment requires that the Stereo Test Generator incorporate an accurate deviation display.

R226 adjusts the CARRIER MODULATION display to precisely 100% (±75kHz dev.) for a carrier correspondingly L+R-modulated by a 400Hz sinewave, and including the 19kHz Stereo Pilot at nominal 9% injection.

**Bessel Nulls**

The 530, as with any Modulation Monitor, is most accurately calibrated using the time-honored and precise "Bessel-Function Nulls." Traditionally, equipment required for this method of adjustment has been beyond easy reach of broadcasters. Recently, however, a circuit which enables these measurements has been developed by our clever Inovonics design team, and a "Bessel Null Calibrator" of incontrovertible accuracy may easily be constructed by station technicians using component parts commonly available through mail-order catalog suppliers. Full constructional details are available from Inovonics upon receipt of a #10 self-addressed, stamped envelope with 2oz. postage.

# Section V

# APPENDIX

The following Section of this Manual contains Parts Lists for the Inovonics Model 530 Modulation Analyzer, Schematic Diagrams of all electronic circuitry, and an explanation of Inovonics' Warranty Policy.

# PARTS LIST

## EXPLANATION OF PARTS LISTINGS

This section contains listings of component parts used in the Inovonics 530. These are listed either *en-masse,* or by schematic component reference designation and may, or may not, specify a particular manufacturer. When no manufacturer is called-out, the term "open" advises that any manufacturer's product carrying the given part number is acceptable.

If a particular component is *not listed at all*, this means that we do not consider it a typical replacement item. Should you need to order an unlisted part, call, write or FAX the factory with a brief description, and we'll do our best to figure out what to send you.

Components with reference designations below 500 are contained on the main printed circuit board. Designations in the 500s are associated with the front panel subassembly; those in the 600s are chassis-mounted components.

## PARTS LISTING

Unless specifically noted by component reference designation below, **capacitors** are specified as follows:

**a:** **Under 100pF** are "dipped mica" type, DM-15 (or CM-05 military series) size designation; "P" value is picofarads, ±5%, 200VDC. Manufacturer open.

**b:** **100pF to 0.47$\mu$F** are of the metallized mylar or polyester variety; whole number "P" values are picofarads, decimal values are microfarads, ±5%, 50VDC or better. The style used in the Model 530 is the "minibox" package with lead spacing of 0.2 inch. **Preferred mfgr.:** WIMA, MKS-2 or FKC-2 series. **Alternates:** CSF-Thompson IRD series or Roederstein KT-1808 or KT-1817 series.

**c:** **1.0$\mu$F and above** are aluminum electrolytic type with radial leads; value per schematic, voltage rating equal to the one being replace. The 2.2$\mu$F, 50V capacitors used extensively for power supply bypass are a high-reliability type: Illinois Capacitor 225 RMR 050M.

| | |
|---|---|
| C1,2 | Capacitor, Ceramic Disc "Safety," .0047$\mu$F, 440VAC; Murata/Erie DE7150 F 472M VA1-KC |
| C64-71,74,76-82 | Capacitor, "High-Q," .0033$\mu$F, 2.5%, 100VDC; WIMA FKC-2 (Polycarbonate) preferred, any equivalent *must* have identical characteristics. |
| CR1-6 | Diode, Silicon Rectifier; (open mfgr.) 1N4005 |
| CR7 | Diode, Power Schottky; (open mfgr.) 1N5820 |
| CR8-30,501-507 | Diode, Silicon Signal; (open mfgr.) 1N4151 or equiv. |
| CR31 | Diode, Silicon Zener, 6.2V; (open mfgr.) 1N4735 |
| F1 | Fuseholder, PC-mount; Littlefuse 345-101-010 with 345-101-020 Cap for ¼-inch fuses, or 345-121-020 Cap for 5mm fuses. (Fuse is normal "fast-blow" in value specified on rear panel for mains supply.) |

| | |
|---|---|
| I501 | LED Indicator, Diffused Pastel Red, T1¾ package; Stanley MVR 5744X |
| I502-504, 521-528 | LED Indicator, Diffused Pastel Yellow, T-1 package; Stanley MAY 3378S |
| I505,530-532, 534,536 | LED Indicator, Diffused Pastel Red, T-1 package; Stanley MVR 3878S |
| I506-508 | LED Bar Indicator, Yellow; Kingbright DC-10YWA |
| I509,510,515,520 | LED Bar Indicator, Red; Kingbright DC-10EWA |
| I511-514, 516-519 | LED Bar Indicator, Green; Kingbright DC-10GWA |
| I529,533,535, 537-544 | LED Indicator, Diffused Pastel Green, T-1 package; Stanley MPG 3878S |
| IC1 | Integrated Cct.; (open mfgr.) LM317-T |
| IC2 | Integrated Cct.; (open mfgr.) LM337-T |
| IC3 | Integrated Cct.; National LM2575 (with AAVID 574602B03700 Heatsink) |
| IC4,16,20,29 | Integrated Cct.; (open mfgr.) CMOS 4024B |
| IC5,7,17,30,51 | Integrated Cct.; (open mfgr.) CMOS 4052B |
| IC6,9,10,11,28 | Integrated Cct.; Raytheon RC4558NB |
| IC8,13,24,34,42,62 | Integrated Cct.; (open mfgr.) CMOS 4053B |
| IC12,14,54,55 | Integrated Cct.; Motorola MC34082P |
| IC15 | Integrated Cct.; (open mfgr.) CMOS 4538B |
| IC18,64,511 | Integrated Cct.; (open mfgr.) CMOS 4051B |
| IC19 | Integrated Cct.; (open mfgr.) CMOS 4069 |
| IC21 | Integrated Cct.; (open mfgr.) CMOS 4073B |
| IC22 | Integrated Cct.; (open mfgr.) CMOS 4013B |
| IC23,25-27,32, 33,35-39,41, 43-50,52,53,58, 60,61,63,508,509 | Integrated Cct.; (open mfgr.) LM353N |
| IC31 | Integrated Cct.; (open mfgr.) CMOS 4584B or 40106B |
| IC57 | Integrated Cct.; Signetics TDA 1578 |
| IC59 | Integrated Cct.; National LM1865N |
| IC501-505 | Integrated Cct.; National LM3914N |
| IC506 | Integrated Cct.; (open mfgr.) CMOS 4066B |
| IC507 | Integrated Cct.; (open mfgr.) CMOS 4017B |
| IC510 | Integrated Cct.; (open mfgr.) CMOS 4042B |
| IC512 | Integrated Cct.; (open mfgr.) CMOS 4532B |
| J1 | AC Mains Connector, PC-mount; Switchcraft EAC303 |
| K1,2 | Relay, SPST Reed; Mouser 431-1412 |
| L1 | Inductor, Switching Regulator; Renco RL1952 |
| L2 | Inductor, 220$\mu$H; Mouser 43HH224 |
| L3,4 | Inductor, 1mH; Mouser 43HH103 |
| L5 | Inductor, 10$\mu$H; Mouser 43LS105 |
| L6 | Quadrature Detector Coil; Toko BKAC-K2318HM |
| Q1,2,5,6,7,12 | Transistor, NPN; (open mfgr.) 2N5088 |
| Q3,4,9,11 | Transistor, NPN; (open mfgr.) 2N3904 |
| Q8,10,504 | Transistor, PNP; (open mfgr.) 2N3906 |
| Q501-505 | Transistor, V-FET; Int'l. Rectifier IRF530 |

Unless specifically noted by component reference designation below, **resistors** are specified as follows:

**a:** **Fixed resistors** with no tolerance specified are ¼-watt, 5%, carbon-film. With 1% tolerance specified, ¼-watt, 1% metal-film. Values are in ohms; K signifies kilohms, M signifies megohms. Manufacturer open.

**b:** **Single-Turn Trimming Potentiometers** (circuit board calibration adjustments) are Beckman 91AR series.

**c:** **Multi-Turn Potentiometers** (for station tuning) have integral knob and are Tocos RJC097PK2-10K

| | 530-00 (U.S.) | 530-01 ("EURO") |
|---|---|---|
| R73 | 1.1K, 1% | 1.07K, 1% |
| R74 | 487, 1% | 536, 1% |
| R165 | 825, 1% | (wire jumper) |
| R166 | 1.5K, 1% | 1.82K, 1% |
| R195 | 3.48K, 1% | 3.57K, 1% |
| R196 | 953, 1% | 1.18K, 1% |
| R197 | 1.58K, 1% | 2K, 1% |
| R256 | 35.7K, 1% | 32.4K, 1% |
| R257 | 634K, 1% | 237K, 1% |
| R503 | 100K,5% | 91K, 5% |

| | |
|---|---|
| R601 | 56-ohm, 5%, 1-watt carbon film |
| S1 | Switch, DPDT Voltage Selector; C&K V202-12-MS-02-QA |
| S501-515 | Switch, Pushbutton; ITT/Schadow D6-04-01 with F14-01 black cap, or F14-04 gray cap. |
| S600 | Switch, SPST Power "Rocker"; Carling RA911-VB-B-0-V |
| S601 | Switch, DPDT Mini-Slide; CW Industries GF-126-0026 |
| T1 | Power Transformer, PC-mount; Signal LP 24-1000 (or direct cross-ref.) |
| TUNER | INOVONICS Part No. 1248 |
| Y1 | Crystal, 3.579545MHz U.S. "Color Burst", HC-49 package; (open mfgr.) |

## MAIL-ORDER COMPONENT SUPPLIERS

The following electronic component distributors have proven to be reputable U.S. suppliers of both large and small quantities of parts. Any semiconductor, IC, capacitor, resistor or connector used in the Model 530 is *probably* available from one or more of these firms. Each supplier publishes a full-line catalog, available free of charge.

**Mouser Electronics** - Call: 1-800-34-MOUSER

**Digi-Key Corporation** - Call: 1-800-DIGI-KEY

**ACTIVE** (div. of Future Electronics) - Call: 1-800-677-8899

# INOVONICS WARRANTY

I **TERMS OF SALE:** Inovonics products are sold with an understanding of "full satisfaction"; that is, full credit or refund will be issued for products sold as new if returned to the point of purchase within 30 days following their receipt, provided that they are returned complete and in an "as shipped" condition.

II **CONDITIONS OF WARRANTY:** The following terms apply unless amended *in writing* by Inovonics, Inc.

A. Warranty Registration Card supplied with product *must* be completed and returned to Inovonics within 10 days of delivery.

B. Warranty applies only to products sold "as new." It is extended only to the original end-user and may not be transferred or assigned without prior written approval by Inovonics.

C. Warranty does not apply to damage caused by misuse, abuse, accident or neglect. Warranty is voided by unauthorized attempts at repair or modification, or if the serial identification has been removed or altered.

III **TERMS OF WARRANTY:** Inovonics, Inc. products are warranted to be free from defects in materials and workmanship.

A. Any discrepancies noted within 90 days of the date of delivery will be repaired free of charge, or the equipment will be replaced with a new or remanufactured product at Inovonics' option.

B. Additionally, parts for repairs required between 90 days and one year from the date of delivery will be supplied free of charge. Labor for factory installation of such parts will be billed at the prevailing "shop labor rate."

IV **RETURNING GOODS FOR FACTORY REPAIR:**

A. Equipment will not be accepted for Warranty or other repair without a Return Authorization (RA) number issued by Inovonics prior to its return. An RA number may be obtained by calling the factory. The number should be prominently marked on the outside of the shipping carton.

B. Equipment must be shipped prepaid to Inovonics. Shipping charges will be reimbursed for valid Warranty claims. Damage sustained as a result of improper packing for return to the factory is not covered under terms of the Warranty and may occasion additional charges.