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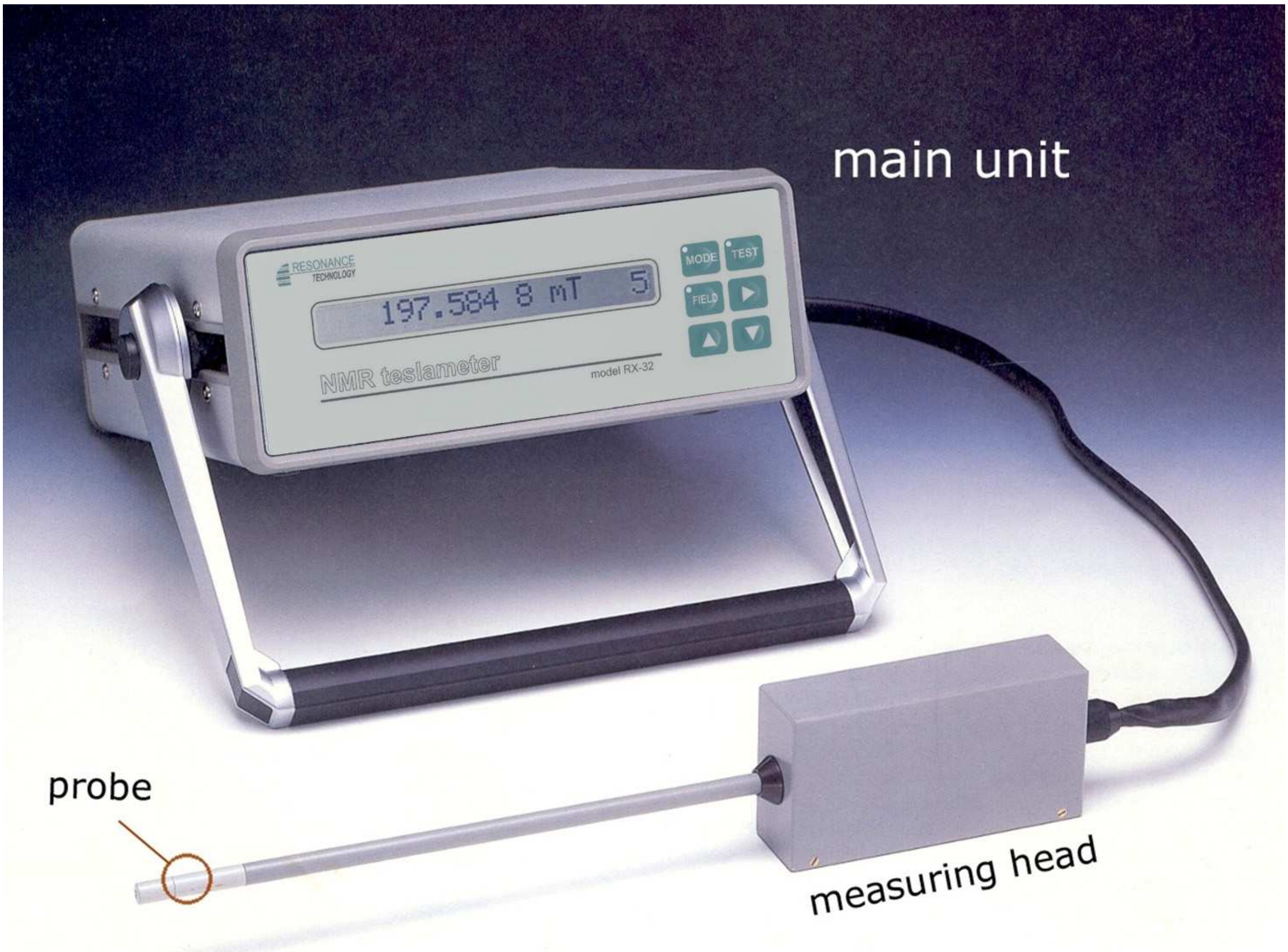
NMR teslameter

model RX- 32b

User manual (ver.2.3)

March, 2008



Overall view of RX-32 NMR teslameter

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SPECIFICATIONS

ELECTRICAL SPECIFICATIONS

Field range:

Middle Field probe	(MF)	standard:	0.760 kGs - 19.10 kGs	(76 mT-1.91T)
Low Field probe	(LF)	(optional):	0.350 kGs – 0.900 kGs	(35 mT- 90 mT)
High Field probe	(HF1)	(optional):	18.00 kGs - 110.00 kGs	(1.8 T-11.0 T)

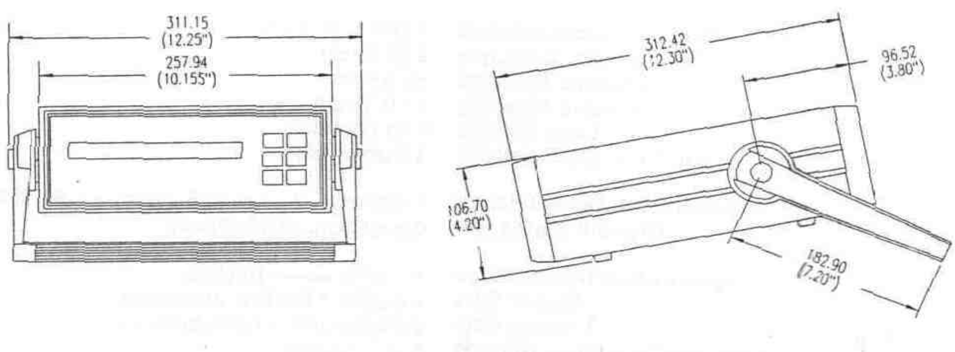
Magnetic field resolution	0.001 Gs
Field gradient tolerance	0.03 %/cm max.
Absolute accuracy	± 5 ppm
Relative accuracy	± 0.1 ppm
Short term clock stability	0.001 ppm/day
Long term clock stability	2 ppm/year
Gradient measurement range	5 mGs/cm - 2 Gs/cm
Gradient resolution	0.3 mGs/cm
Frequency and search range	1.5 MHz – 82 MHz (760 Gs – 19,10 kGs)
Search rate	5.0 kGs/s max.
Tracking rate	0.9 kGs/s max.
Response time while tracking	2 ms - 130ms
Gate time:	
low resolution mode	12 ms
high resolution mode	117 ms
Power requirements	50/60 Hz, 115/230 V, 30 W
Temperature range: operating	5℃ - 40℃
storage	0℃ - 50℃

MECHANICAL SPECIFICATIONS

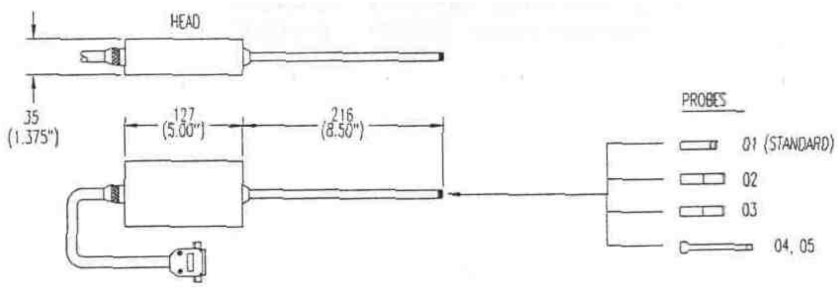
NOTES:

- The RX-32 includes main panel, measuring head and MF probe.
- Dimensions are in millimeters and (inches).
- Total teslameter weight is 5.5 kg (6 Ibs), including the measuring head which alone weights 1.12 kg (2.5 lbs) and probe tip which alone weights 5.2g (0.18oz).

MAIN PANEL:



HEAD: standard NMR measuring head with 300 cm cable and set of probes



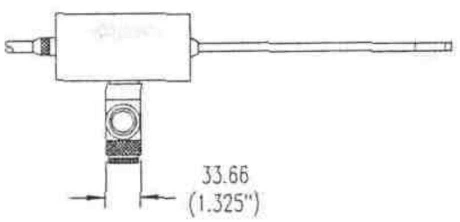
MODEL PROBE DESCRIPTION:

SAMPLES		SIZE (mm)	FIELD RANGE
Standard Middle Field	(MF probe)	8.0 x 39.0	760 Gs – 19.100 Gs
Low Field	(LF probe)	11.5 x 50.0	350 Gs - 900 Gs
High Field	(HF probe - # 1)	8.0 x 45.0	18 kGs – 110 kGs
Miniature Middle Field	(MMF probe)	5.0 x 35.0	2.100 Gs – 10.4 kGs
High Field	(HF probe - # 2)	10.5 x 50.0	13.9 kGs – 31 kGs

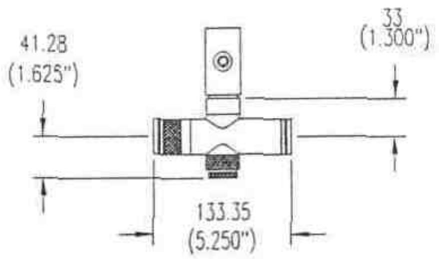
Special holder (RX-09 type) is designed to attach to the measuring head and be mounted between the coils of an electromagnet. The 133.4 mm dimension may be varied to fit the distance between magnet coils wall.

HEAD HOLDER

With measured head attached



stand alone



1.0 INSTRUMENT PREPARATION

1.1. AC POWER CONNECTION

WARNING! FOLLOW THESE INSTRUCTIONS OR DAMAGE MAY RESULT !

Fig. 1.0 depicts the rear-panel power module containing the power switch, line cord receptacle, line fuse. Selection of operation from either 115 VAC or 230 VAC line is established by producer.

1) Turn the power switch to the OFF (O) position and remove the line cord.
2) Insert a narrow flat screwdriver behind the access slot and gently pry open the access door. Flip the door down.
3) Grasp the voltage programming drum and pull it straight out of the module
4) Rotate the drum to show the correct voltage, then insert the drum into the module.
5) Close the access door and insert the line cord.

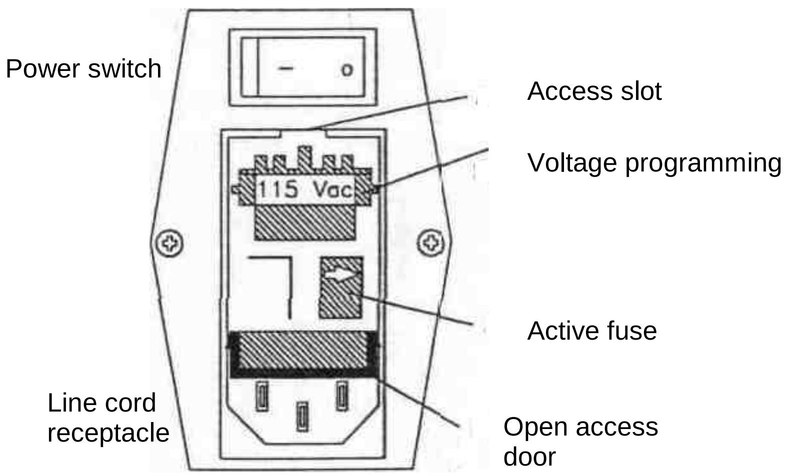


FIGURE 1.0 Power receptacle module

1.2. MEASURING HEAD CONNECTION

Fig.1.1 is a view of the rear-panel of the meter. Connect the measuring head as follows:

1) Turn the power switch OFF - (0) position !
2) Insert the measuring head's connector (15-pin "HD") into the mating receptacle marked "NMR HEAD".
3) Secure the connector with the captive screws.

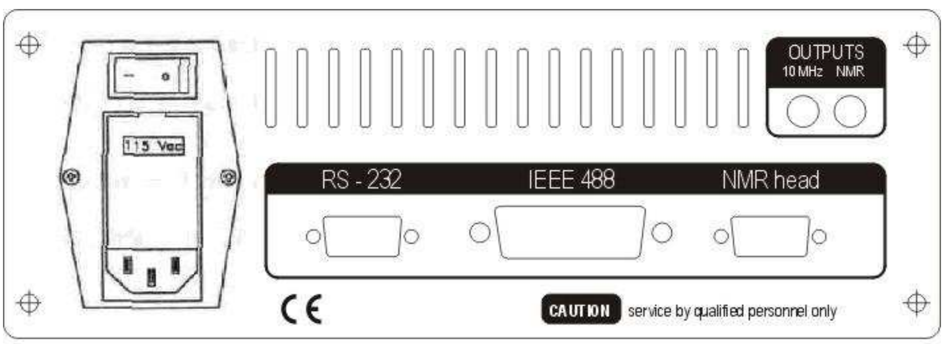


FIGURE 1.1 Rear panel of instrument

1.3. NMR PROBE CONNECTION

As seen in Fig.1.2, connect the probe tip to the head by gently inserting the pin within the tip into the receptacle within the head stem. Once the two mate gently push the two together. Upon contact screw the tip onto the stem (right-hand thread).

WARNING! DO NOT USE EXCESSIVE FORCE OR DAMAGE MAY RESULT TO THE THREADS !

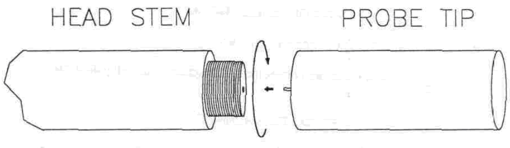


FIGURE 1.2 Head/probe connection

1.4. POWER UP

Locate the power switch on the rear-panel power module and press the side marked " | ". A message will scroll across the display which reads:

NUCLEAR MAGNETIC RESONANCE MODEL RX-32 v. x.x

The software version number appears at the end of the message, such as v.1.8. The message will scroll across the display twice . Then the meter will proceed to the next step in the power-up process (the message can be bypassed by pressing any pushbutton switch).

Next the status of the communication port is displayed as either

RS-232 ON ! or IEEE-488 ON !

depending upon which of the two ports has been activated.
If the measuring head and probe are connected and functioning properly, the next message will be:

PROBE TEST RUNNING

followed by

LOW FIELD PROBE or MIDDLE FIELD PROBE or HIGH FIELD PROBE,

depending upon which probe is attached. And then

WARM UP! PLEASE WAIT

It takes 10 minutes needed to pick up temperature of Oven Controlled Crystal Oscillator (OCXO) to value where its stability of frequency reaches maximum. After warming time the meter will begin the measurement process.

2.0 UNDERSTANDING NMR

2.1. WHO SHOULD READ THIS ?

If you've never measured a magnetic field or have done so using a Hall effect teslameter or a flux meter you should read this section. It will help you understand how the measurement is made and define terminology you may not be familiar with. Overall this information will help you use the RX-32 to its fullest potential.

2.2. WHAT IS NUCLEAR MAGNETIC RESONANCE ?

Electrons and certain atomic nuclei behave as though they rotate about an axis, as seen in Fig. 2.1(a). This *angular moment* is called "spin". Nuclei that have an odd number of protons or neutrons exhibit this property. Examples are hydrogen, deuterium and nitrogen. Those that have an even number of protons and neutrons, such as carbon and oxygen do not. A spinning particle can be viewed in much the same way as a loop of wire carrying an electric current. Since the particle has an electric charge associated with it, the spin gives rise to a magnetic dipole, or *magnetic moment,* oriented along the axis of the spin.

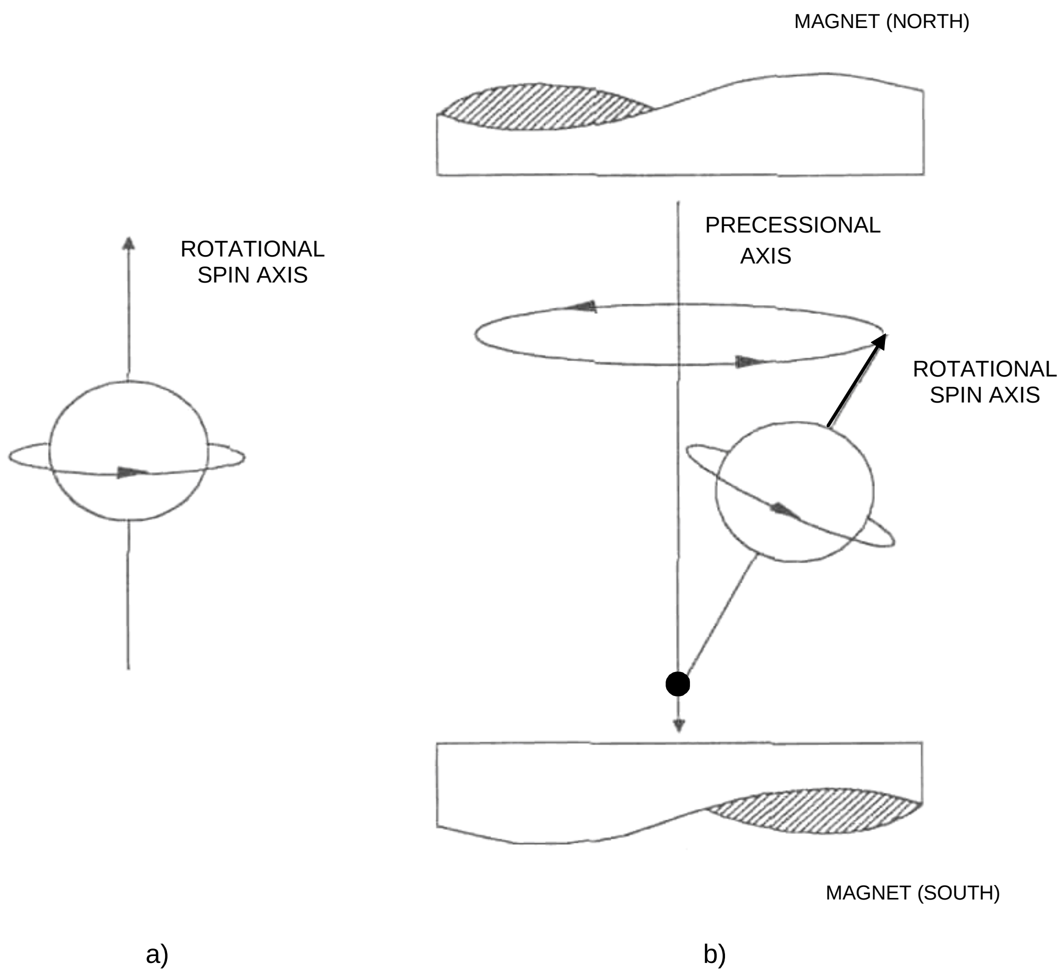


FIGURE 2.1 Precessional motion caused by external magnetic field

When the spinning particle is placed in a steady, uniform magnetic field the field exerts a torque on the dipole. This force causes the particle to assume a *precessional motion* around the direction of the external field, similar to a gyroscope, as seen in Fig. 2.1(b). This orientation corresponds to a specific energy state. More than one orientation is possible, and the number of possible energy states depends upon the number of protons and neutrons in the particle. The single electron or proton can have two energy states – Fig. 2.2(ab).

If a high frequency alternating (AC) magnetic field is introduced the nucleus will be provided enough energy to undergo a transition from one energy state to another, as seen in Fig. 2.2(b). This condition is known as ***N****uclear* ***M****agnetic* ***R****esonance (NMR).*

This phenomenon will only take place when the frequency of the AC magnetic field is directly proportional to the intensity of the external direct (DC) magnetic field. Hydrogen's resonant frequency is 42.5775 MHz/Tesla, deuterium's is 6.536 MHz/Tesla and the electron's is 28.026 GHz/Tesla.

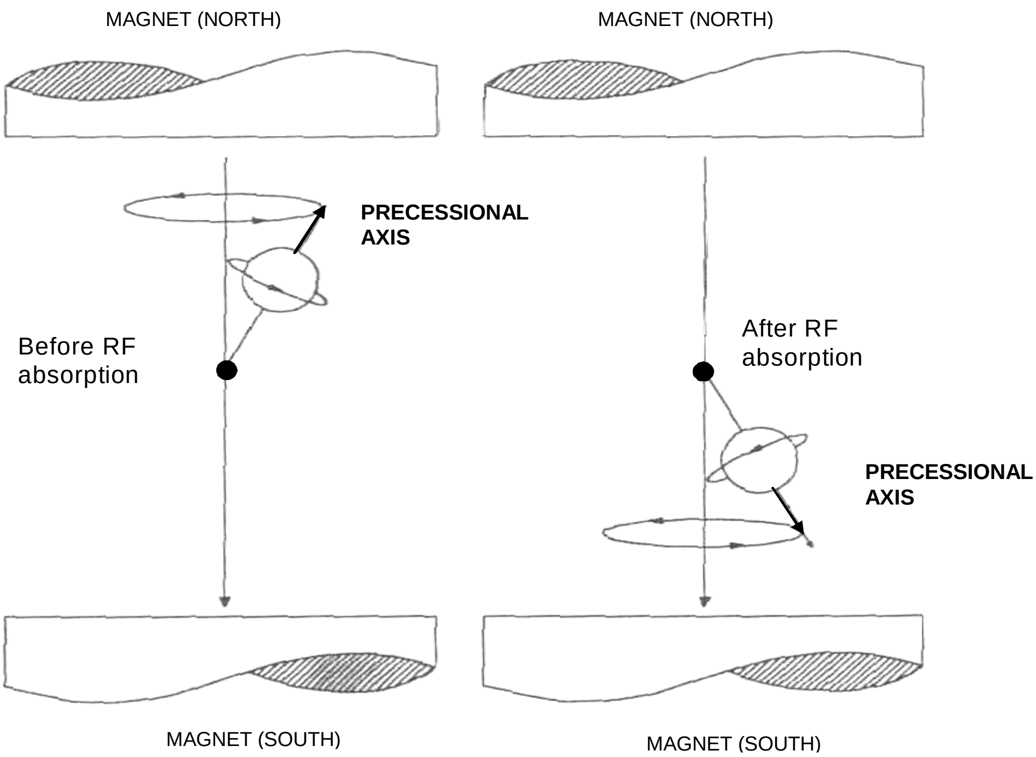


FIGURE 2.2 Energy states of precessing nucleus

As we have seen at Fig.2.2 – radio frequency (RF) energy, after be absorbed by nucleus during NMR – is falling to the lower value, what is an evidence of NMR signal.

2.3. HOW MAGNETIC FIELD INDUCTION IS MEASURED BY NMR

One way to determine the flux density of an unknown magnetic field is to use a specific element, say hydrogen, as a sensing medium and determine its resonant frequency at measured field. Pure water serves well as a sensing medium because there is high abundance of hydrogen. The oxygen in water does not possess a magnetic moment and therefore neither contributes to or interferes with hydrogen's response. In order for the element to reach a higher energy state it must absorb energy from another source.

A common technique is to expose the element (called a sample or probe) to an adjustable radio frequency (RF) energy source, measure the frequency at which the element absorbs the energy and convert this value directly to tesla or gauss.

NMR meters use circuits and techniques common to broadcast radio receivers. An typical version is shown in Fig. 2.3. Due to the physical characteristics of the probe the range of measurement is usually very limited, so the probe has to be designed to cover specific ranges, such as 0.1-1.5 T for example.

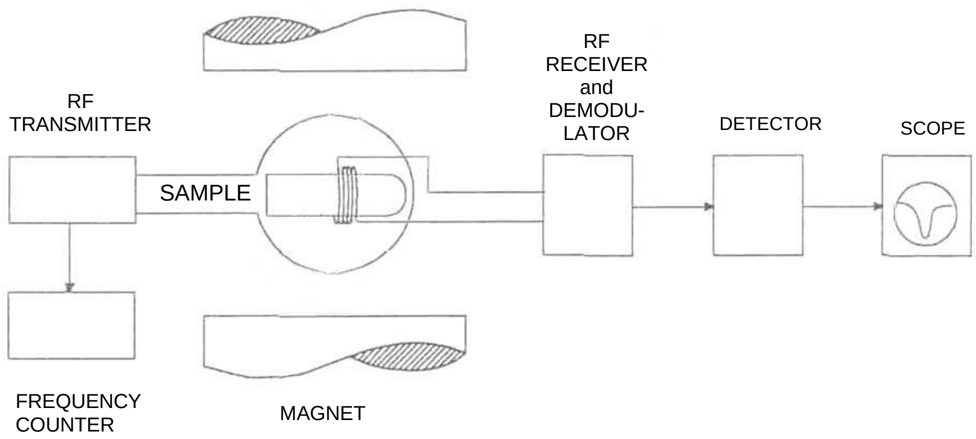


FIGURE 2.3 Basic NMR measurement technique

Very important requirements for NMR existence are:

- steady, stable (DC) magnetic field source,
- RF generator,
- sample (with nuclei possesing “spin moment”) which is placed inside of DC magnetic field and **simultaneously** inside of RF radiation source,
- both magnetic fields (DC and RF) should be **mutually perpendicular.**

The tedium of manual tuning was eventually eliminated by adding circuitry that automatically adjusted (swept) the transmitter frequency until absorption was detected. The transmitter frequency was then locked in place and the frequency is converted to gauss or tesla and presented to an analog meter or digital display. Further advances were made in accuracy by employing noise reduction techniques. Using a secondary coil, the magnetic field in which the sample is located is slightly modulated. The output of the sample is then synchronously demodulated to recover the original signal.

At early 80-years was developed a new NMR measurement process called a fast-scan technique, which has been incorporated now in the RX-32 model. In this configuration the same coil is used as both a transmit and receive antenna, as seen in Fig. 2.4

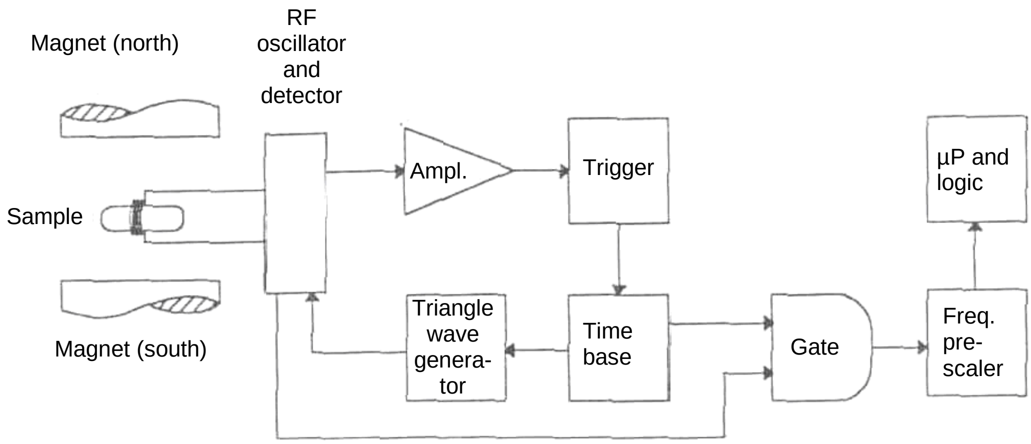


FIGURE 2.4 New NMR measurement technique

The frequency starts at 1.5 MHz and is swept up at a very precise rate. If no NMR signal is detected the oscillator will reach a maximum 82 MHz. At this point the process is reversed and begins sweeping down at the same rate until it again reaches 1.5 MHz.

If, during the sweep, an NMR signal is detected the signal's: amplitude, width and overall quality are measured. Rather than allowing the transmitter's frequency to continue sweeping to its full minimum or maximum point - it is immediately reversed until the next NMR signal is detected.

This process continues indefinitely or until the meter loses the NMR signal altogether. When using hydrogen as a sensing medium the instrument range is 0.035 T - 1.91 T (350 Gs –19.1 kGs). With this technique it is possible to cover most of this range with one probe.

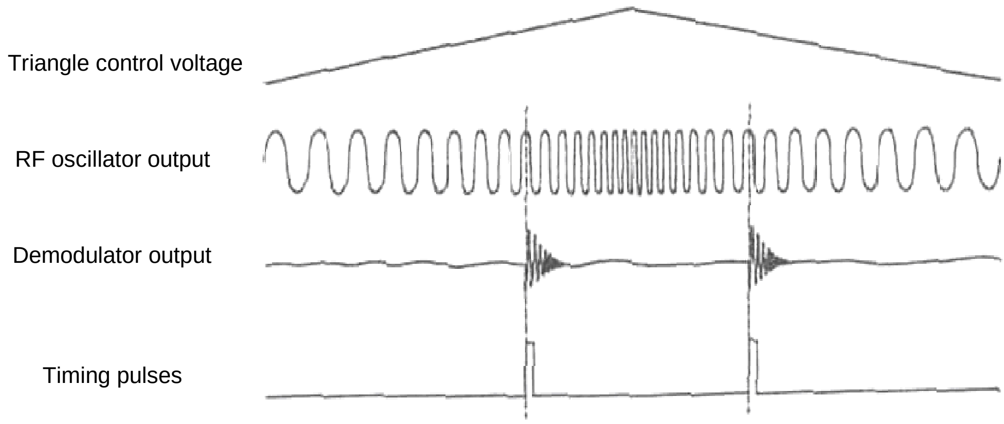


FIGURE 2.5 Teslameter internal timing

2.4. LIMITATIONS OF NMR MEASUREMENT

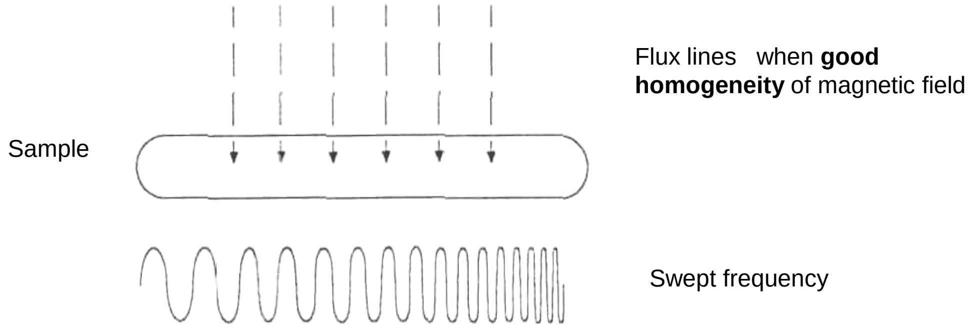
Regardless of which technique is used to measure NMR there are certain limitations that the user must be aware of:

1) The field to be measured must have a **high degree of *homogeneity*** (very evenly spaced flux lines) - see Fig. 2.6. A field with very evenly spaced the flux lines is said to have low *gradient.* In fields with low gradient the majority of elements in the probe will be resonating simultaneously, creating an NMR signal with large amplitude and narrow width. But as gradient becomes higher there will be more resonant frequencies and the overall NMR signal will have lower amplitude and greater width. At some point the signal quality will become too poor to process.

2) The time it takes to determine the value of the unknown field depends upon the rate at which the transmitter frequency is swept. This is known as the *Search rate* and may take as long as several seconds.

3) Only static or relative slowly varying fields can be measured using NMR. The rate at which the instrument can keep up with changes in the field and still provide accurate results is known as the *Tracking rate.*

4) Unlike Hall effect sensors this NMR meter is incapable of sensing the polarity of the field measured.



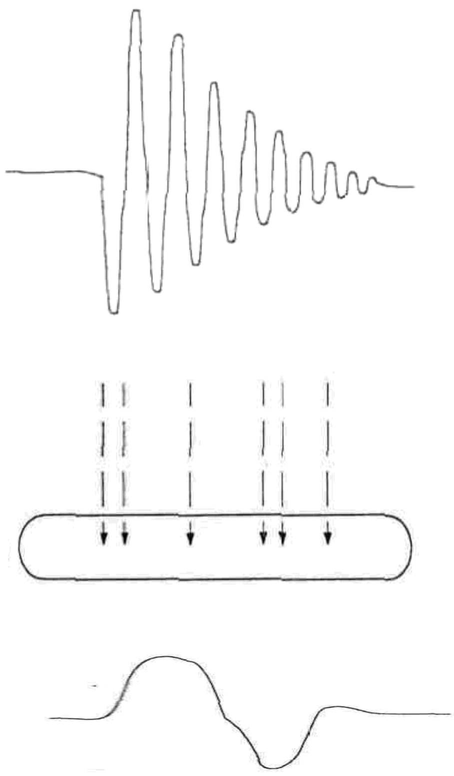


FIGURE 2.6 How magnetic field gradient affects the NMR signal

2.5. ADVANTAGES OF USING THE RX-32 TESLAMETER

The RX-32 offers the following improvements in the measurement of magnetic field intensity by means of NMR techniques:

1) The use of a **single transmit / receive coil** allows the probe to be smaller, allowing access into narrower spaces.

2) Since there is **no modulation coil** there is no disturbance of the field being measured. Rotation of the probe perpendicular to the field direction does not affect the accuracy of the measurement.

3) The **search** and **tracking of NMR signal** is exactly the same process, so tracking and measure of sweeped magnetic field are significantly faster than what has been available with other NMR teslameters.

4) This technique accommodates a much wider range of measurement for a **single probe**, reducing expense and eliminating the need to change probes during the measurement process.

5) The design of **really automatic full range magnetic field searching** reduces the time it takes to determine the magnitude of an unknown field.

6) The instruments can **tolerate higher gradients** than many other NMR teslameters.

7) The instrument is small, lightweight, rugged and **very easy to use**, allowing it to be used in applications beyond the classical laboratory setting, such as incoming Inspection and Calibration Departments.

8) The instrument can present graphical, qualitative **indications of gradient and NMR signal strength** - useful tools when attempting to determine the quality of the field before making actual quantitative measurements.

3.0. INSTRUMENT CONFIGURATION

3.1. FRONT PANEL FEATURES

Fig. 3.0 depicts the front panel, consisting of 20-character LCD display, six momentary contact dome switches and three LED indicators integral to the *MODE*, *TEST* and *FIELD* switches. Indicators are bright when signalled function is activated. Data showed on the display are: actually measured field induction, units of field and number of actually switched on subrange.

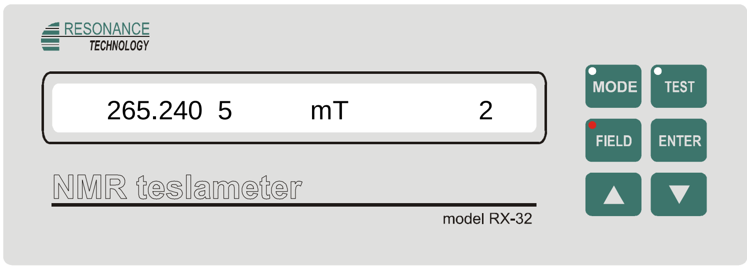


FIGURE 3.0 Instrument front panel

3.2. MENU OPERATIONS

The instrument's operating characteristics can be changed by pressing either the main function buttons: *FIELD*, *MODE* or TEST switches. This stops the measurement process and displays one of a number of options. By pressing the ▲ *or* ▼ switches you can scroll through each option in a circular fashion – see full menu at page 34 and Fig. 3.1.

Note two attributes in the menus; the *cursor* (_) and the *more* (→) symbol. Whenever a selection is made the *cursor* will move to a new location on the display and serves as a guide. The (→) symbol indicates that there is more information that will follow.

Once you have located the option you wish to change press *ENTER*. The cursor will move to the next item that can be changed in that option. Use the ▲ *or* ▼ switches to change the setting, then press *ENTER*. If the (→) symbol is present the *cursor* will move to the next item that can be changed and the process will continue. Otherwise the *cursor* will move back to the beginning.

From this point you can move to another option or press the *FIELD*, *TEST or MODE* switches to exit the menu mode and resume normal operations.

3.3. OPTIONS IN THE FIELD MENU

The options available for the *FIELD* menu are (see Figure 3.1):

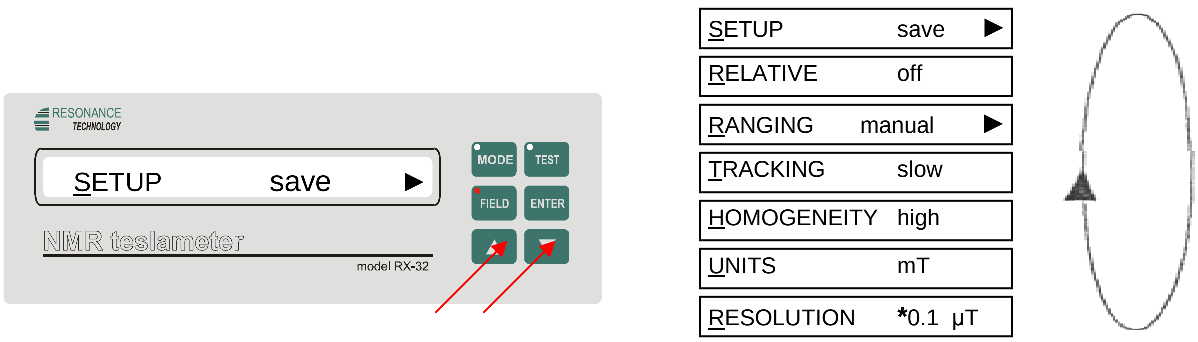


FIGURE 3.1 Options available from the field menu

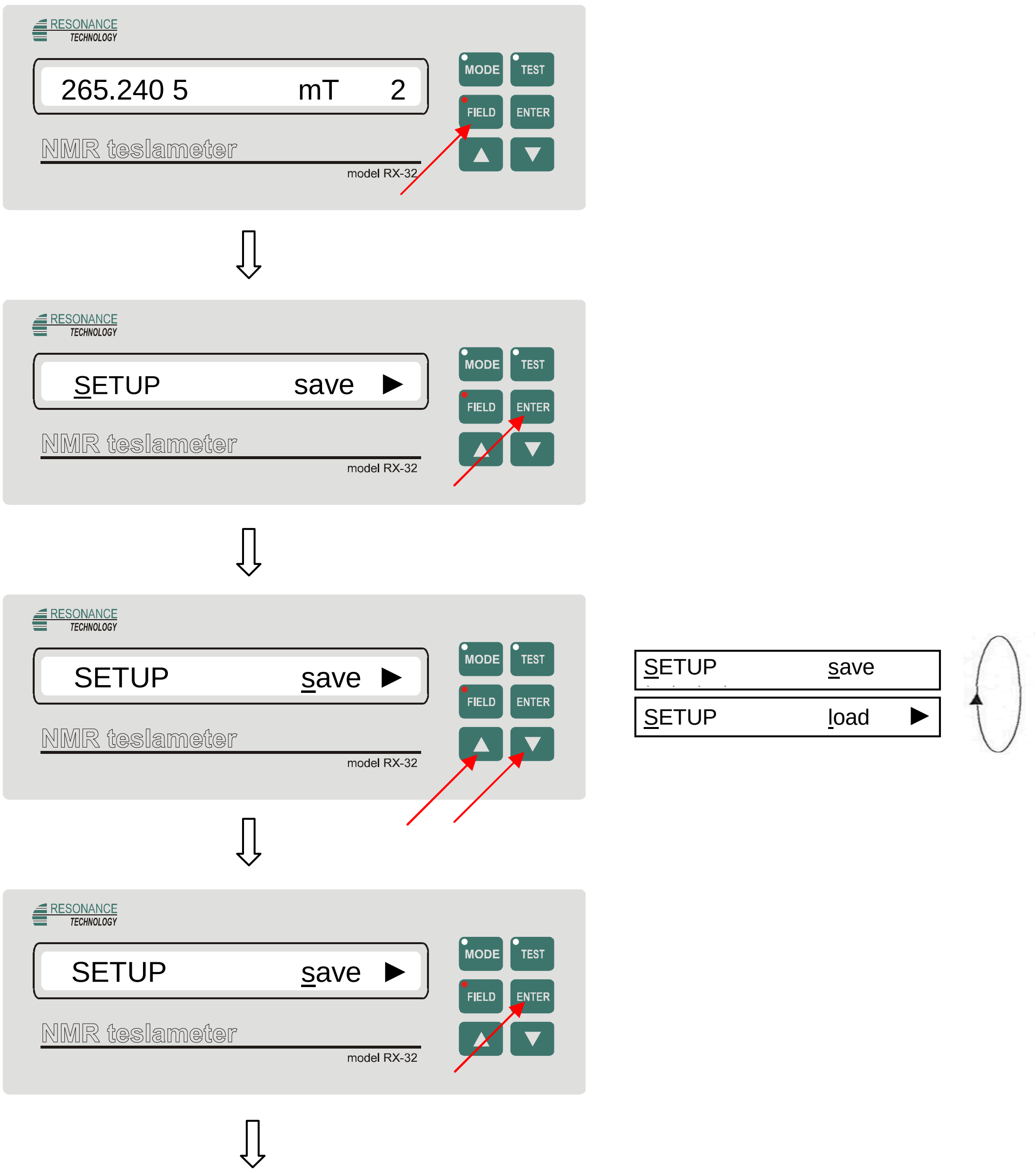
3.3.1 SETUP SAVE/LOAD

The configuration of the instrument, called a *SETUP*, can be permanently stored in the instrument's memory and later retreived, automatically programming the instrument without the need to manually reprogram each characteristic. This feature is particularly useful if the instrument is going to be used for a variety of unique tasks that are repeated on a regular basis. For example, the meter might be used once a month to inspect the same type of magnets. The instrument can be configured for this task and the settings saved. Each month the inspector can configure the instrument in one easy step.

To *SAVE* a setup, enter each menu and program each option as you wish, such as resolution, tracking speed, comm port settings, etc. Then, as shown in Figure 3.2, select the *SETUP SAVE/LOAD* option, select *SAVE* and then select one of the nine possible storage locations. The meter will take a moment to save the present settings.

To *LOAD* a setup select the *SETUP SAVE/LOAD* option, select *LOAD* and select one of the nine possible storage locations. When finished the meter is configured according to the parameters that were previously saved in that location.

NOTE: Storage location "1" is always used to configure the instrument upon power-up.



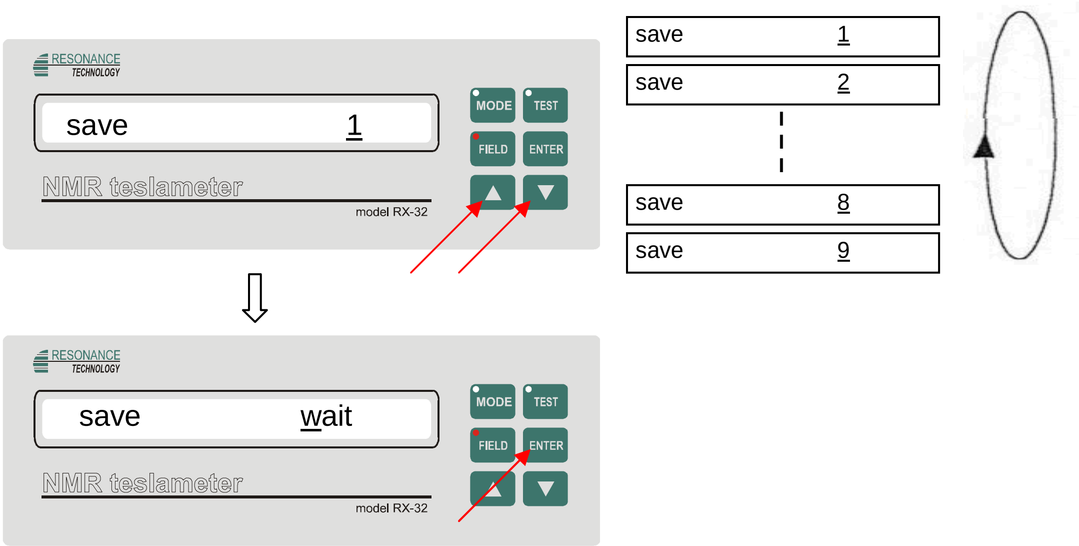


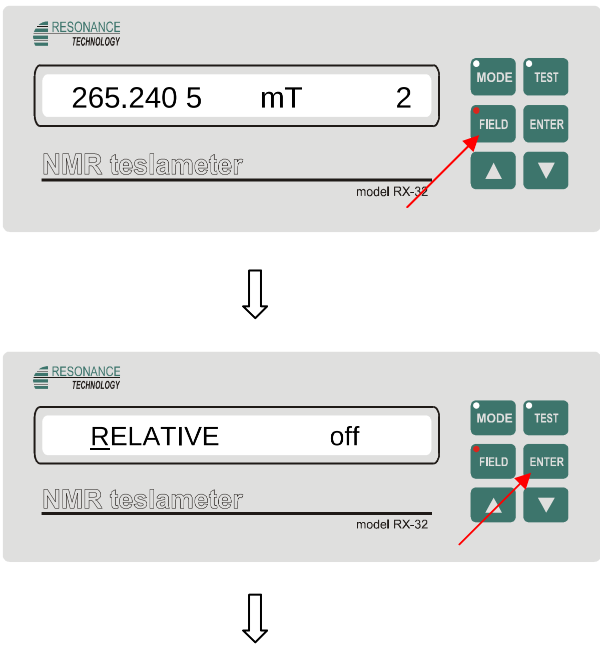
FIGURE 3.2 Setup save/load option

3.3.2 RELATIVE READING

You can specify a value that you would like subtracted from all future readings. This is particularly useful if you wish to observe small variations within a large magnetic field. For example you may be measuring a batch of permanent magnets that should measure around 300 mT. You can program a *RELATIVE* value of 300 mT. From that point all readings will reflect the difference from 300 mT.

NOTE: This is the only mode in which the meter will display a signed reading. As mentioned in Section 2.0 under normal conditions the meter is insensitive to field polarity and the readings will always be unsigned.

As seen in Fig. 3.3 you must first turn the *RELATIVE* option *ON*. Each digit of the *RELATIVE* value is individually programmed (0-9) using the *UP* or *DOWN* switches. When you turn the *RELATIVE* option OFF the previous value will be retained for future use.



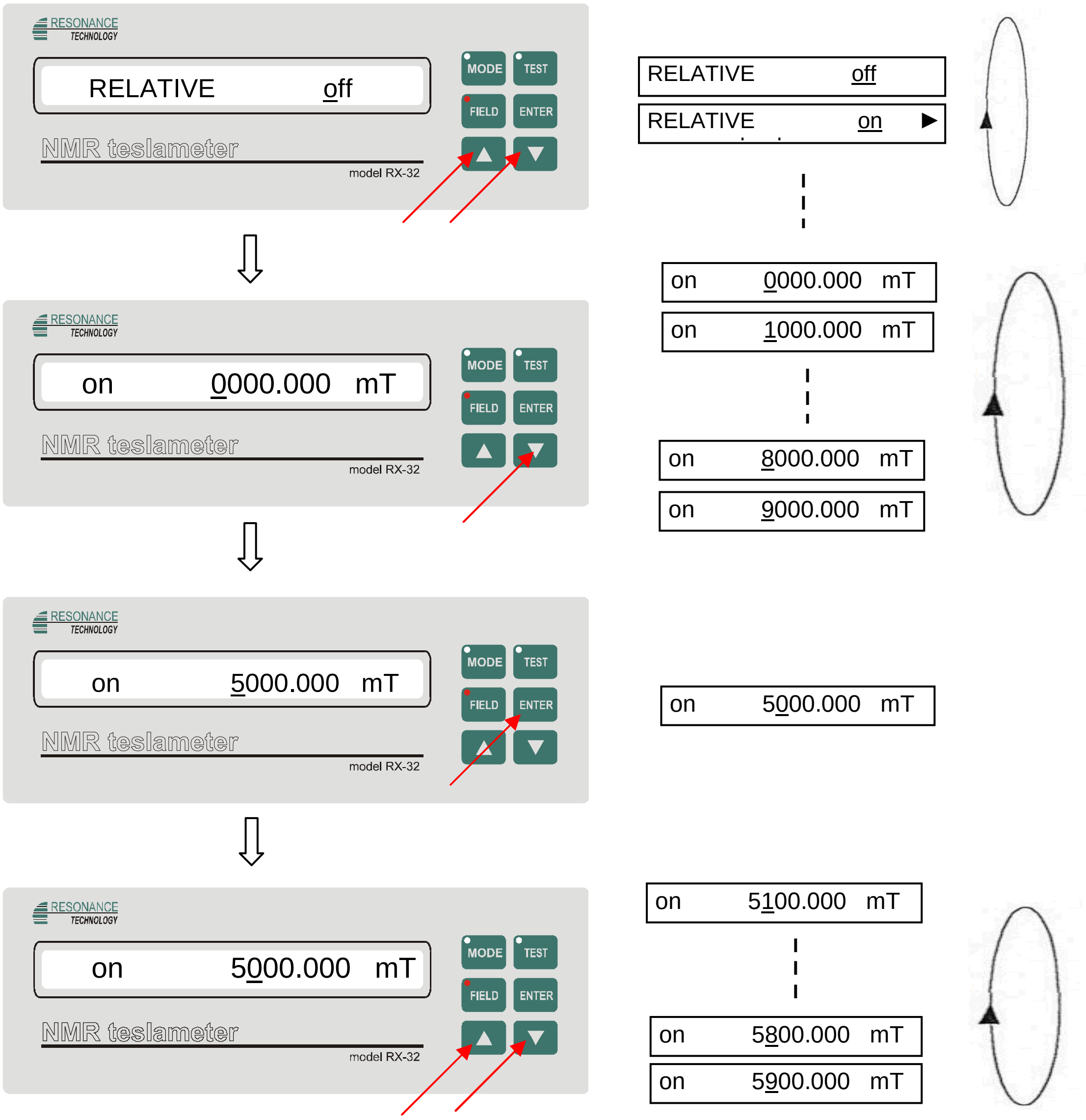


FIGURE 3.3 Relative option

3.3.3. RANGING

The magnetic range of the probe is divided into seven (7) subranges. You can select a specific range or you can allow the instrument to search for a subrange appropriate for present field conditions, often referred to as "autoranging".

The seven subranges are not necessarily equal in span. For instance using the Middle Field probe, which has an overall range of 0.076 T – 1.91 T (760 Gs – 19.1 kGs), the first subrange might cover 0.076 T - 0.22 T (760 Gs - 2200 Gs) while the second subrange might cover 0.2 T - 0.49 T (2000 Gs - 4900 Gs). The *FIELD RANGE* option in the *TEST* menu (Section 3.6.3) allows you to inspect these ranges.

From the *RANGING* menu, shown in Figure 3.4, select either AUTO or *MANUAL.* In the latter case select any range from 1 to 7. When the instrument returns to the measurement mode the range number will appear in the right-most digit of the display.

NOTE: The automatic selection can only be used if the *HOMOGENEITY* option has been set to *HIGH.* See Section 3.4.5. Otherwise the instrument will issue a warning and will revert to a *MANUAL* setting, selecting the range that was last used.

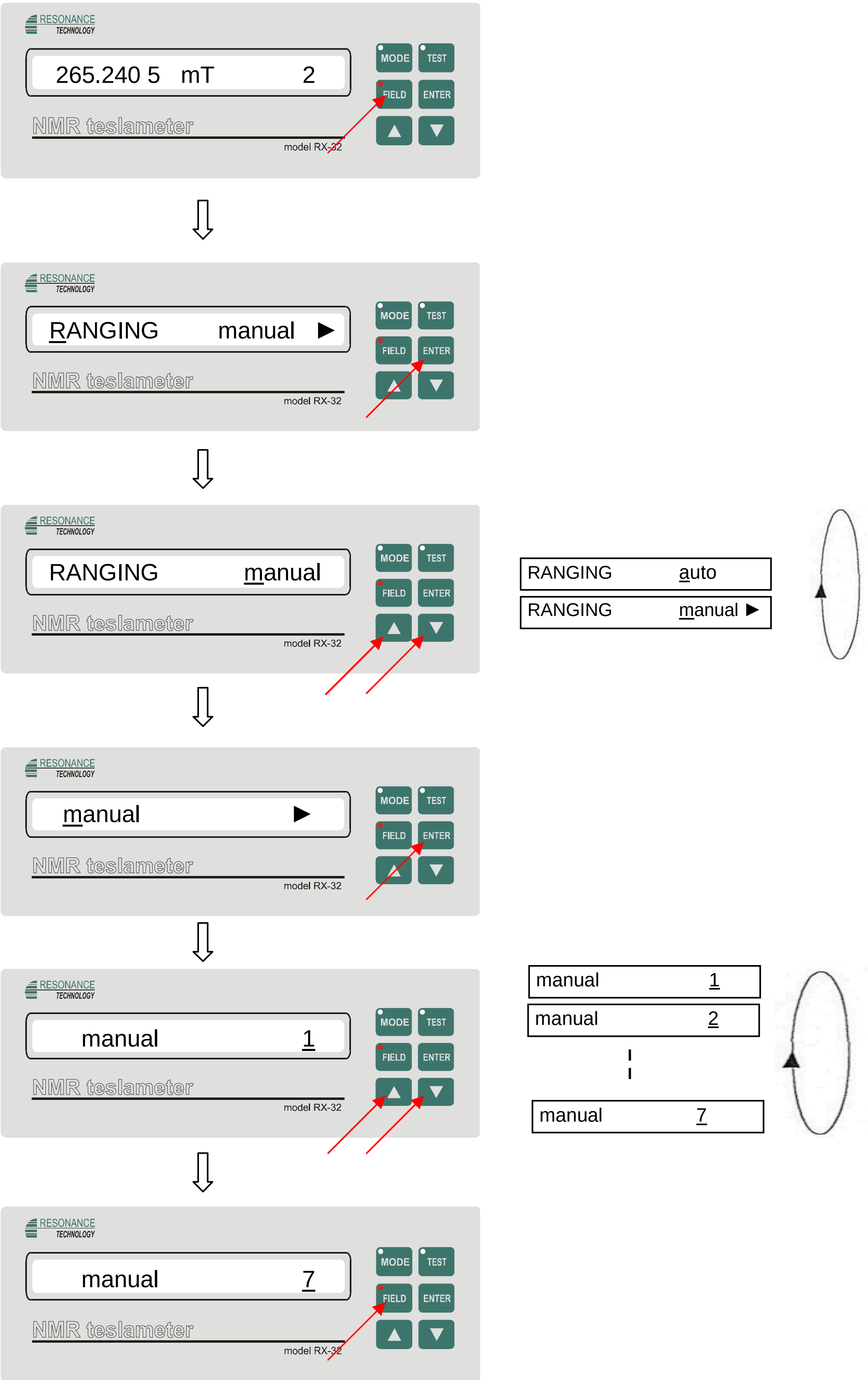


FIGURE 3.4 Ranging option

3.3.4. TRACKING

You can select the rate at which the instrument attempts to track changes in the magnetic field: slow or fast, using the ***TRACKING*** option shown in Figure 3.5.

As mentioned in Section 2.0 the instrument is capable of keeping up with changes in the magnetic field as fast as 90 mT (900 Gs) per second. To accomplish this there may have to be some sacrifices in the resolution of the reading. The slowest tracking rate results in the highest resolution but slows down the autorange feature and may not be able to keep up with fast changes in the field.

NOTE: If high resolution has been selected (See Section 3.4.7) and a fast ***TRACKING*** speed is selected the instrument will issue a warning and will select a resolution that is appropriate for the speed you have selected.

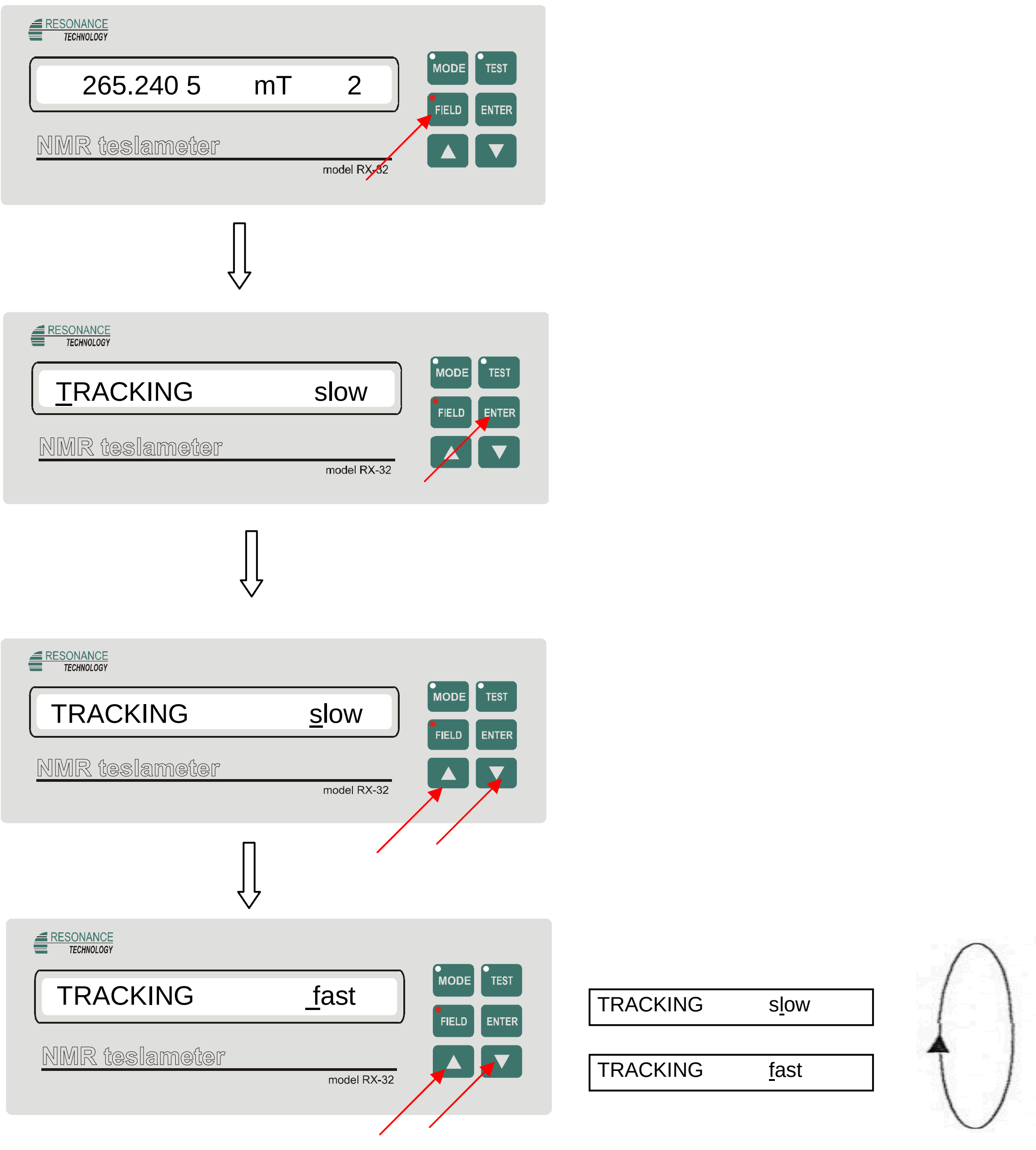


FIGURE 3.5 Tracking option

3.3.5. HOMOGENEITY

You can specify the quality of the field (estimated as field gradient value) as **LOW** homogeneity or ***HIGH*** *homogeneity of measured field,* using the option shown in Fig. 3.6. In the ***HIGH*** setting the meter is capable of providing high resolution readings in fields with gradients as high as 0.02%/cm. With the ***LOW*** homogeneity of field setting this can increase to nearly 0.05%/cm, but the accuracy of the reading may not be as great. The **LOW** setting is intended to accomodate fields that most other NMR meters are often incapable of measuring. The **VERY LOW** setting is not yet available (for service using only).

NOTE: When the **LOW** setting is selected you may not use the **AUTO** range selection feature. The meter will issue a warning and reconfigure for ***MANUAL*** range if this happens.

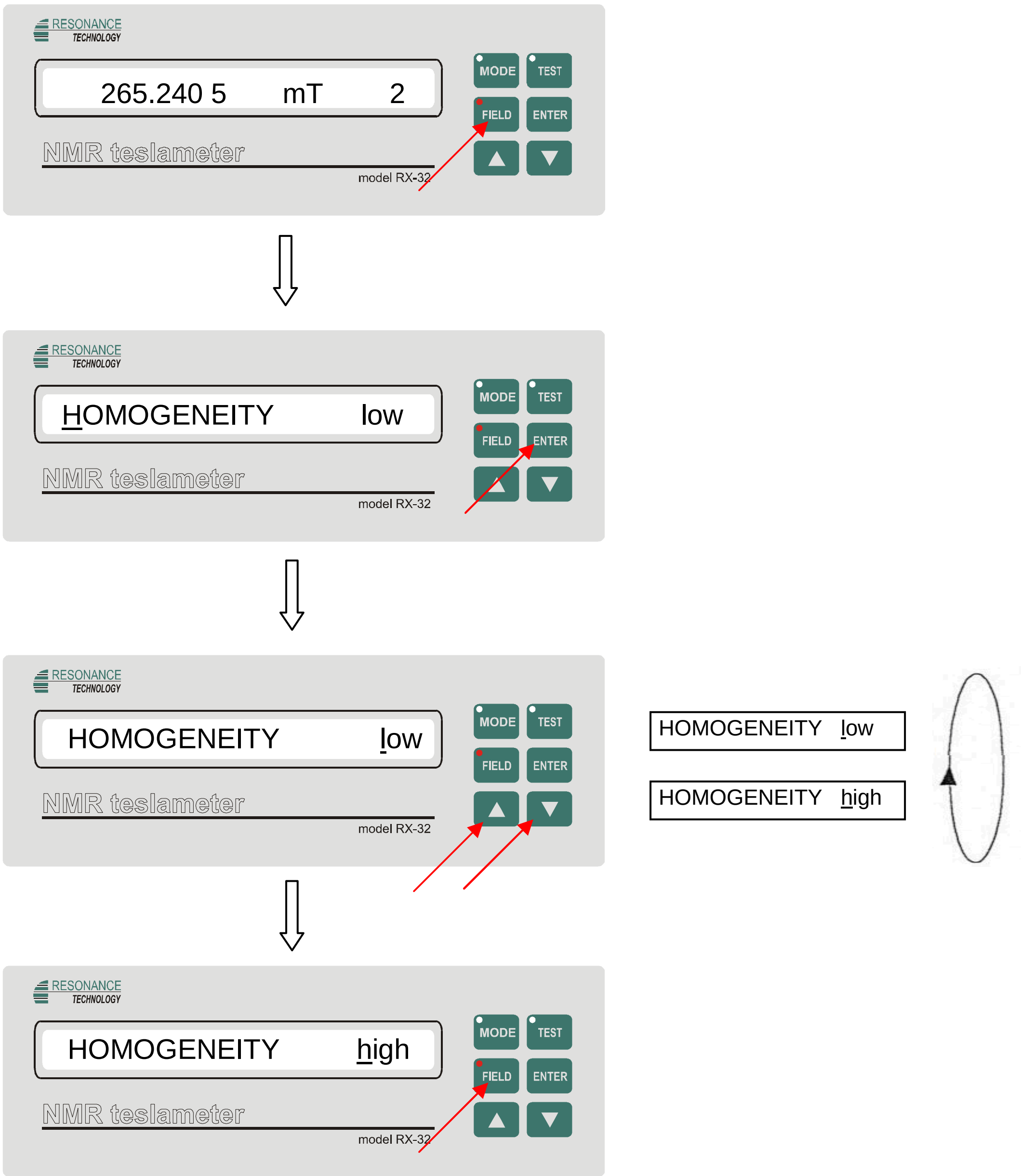


FIGURE 3.6 Homogeneity option

3.3.6. UNITS

You can select magnetic fields units either gauss (Gs), tesla (mT) or kilohertz (kHz) as the unit of measure using the *UNITS* option shown in Fig. 3.7. In the kilohertz mode the reading relates to the resonant frequency of the sample material, as discussed in Section 2.0.

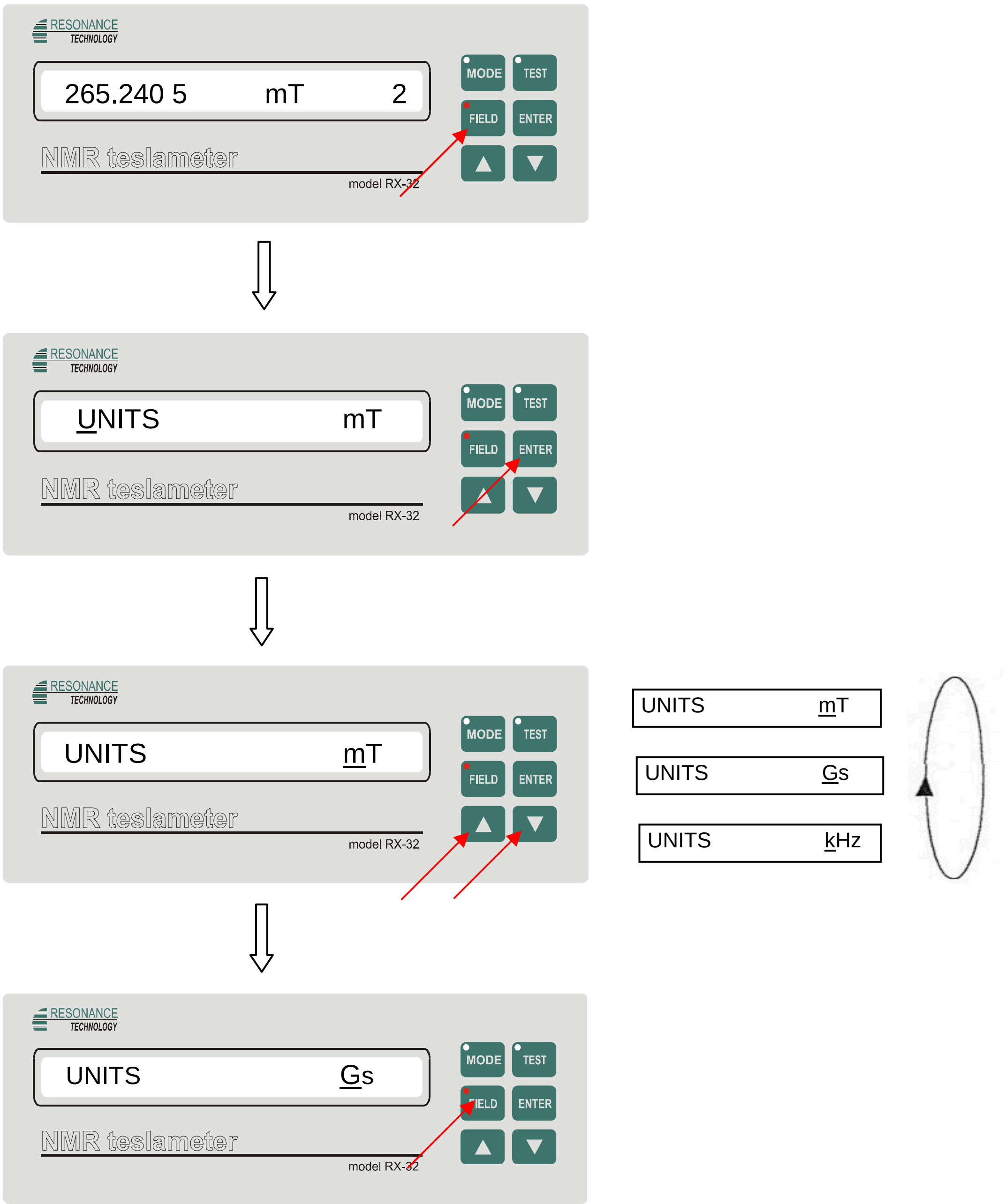


FIGURE 3.7 Units option

3.3.7. RESOLUTION

You can select various degrees of resolution and filtering using the ***RESOLUTION*** option shown in Fig. 3.8. Lower resolution results in faster search and tracking speeds. Several settings allow you to engage a digital filter to stabilize noisy readings.

NOTE: The use of a high ***TRACKING*** speed requires the use of a lower ***RESOLUTION***. If fast ***TRACKING*** and high ***RESOLUTION*** are both selected the instrument will issue a warning and a lower resolution will be selected.

NOTE: The use of the digital filter will cause a slight reduction of ***TRACKING*** speed.

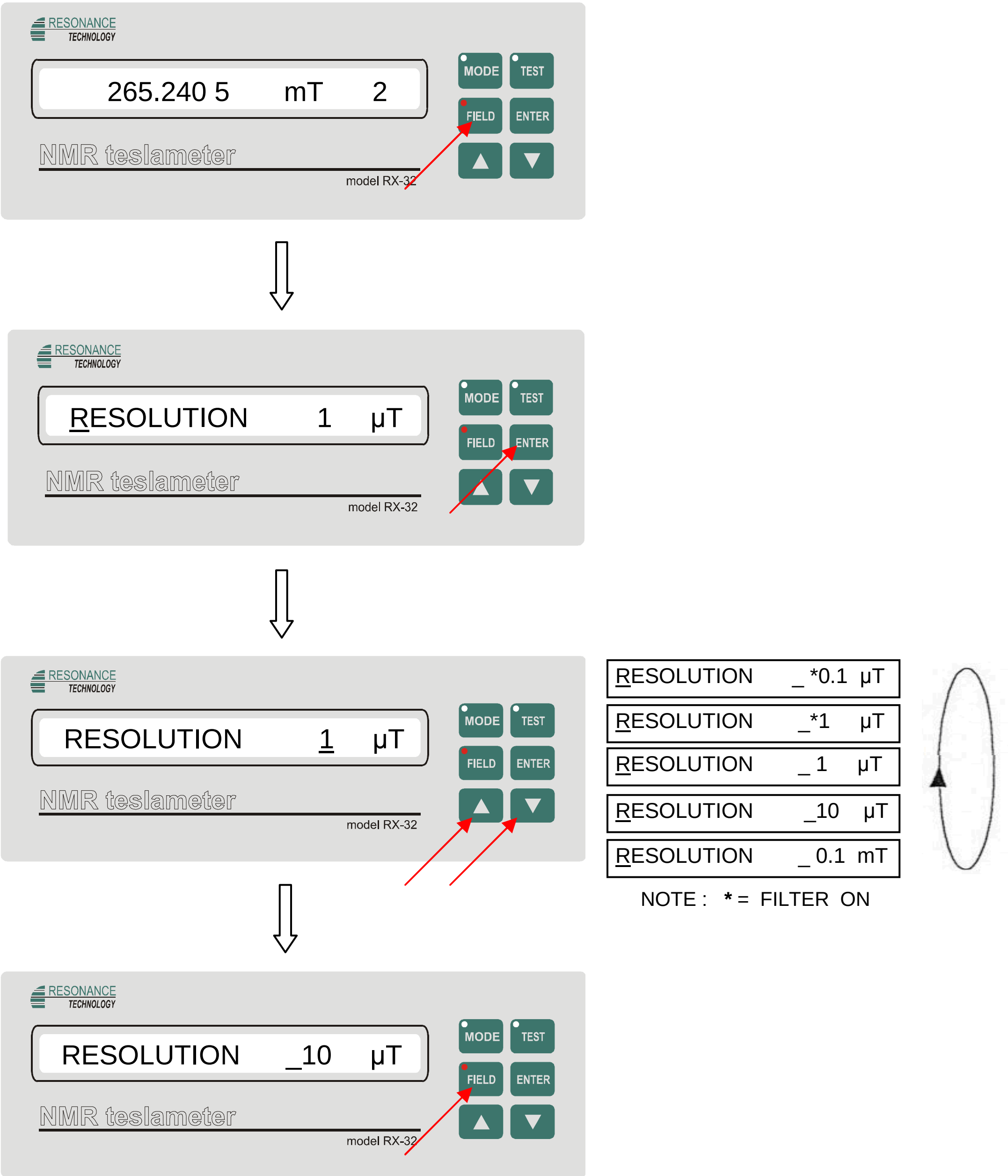
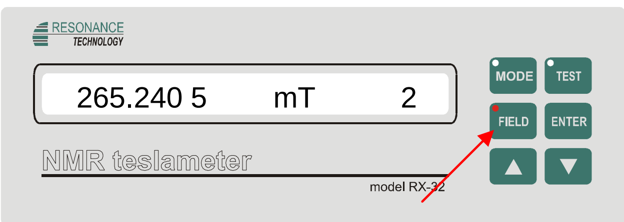


FIGURE 3.8 Resolution option

3.4. OPTIONS IN THE MODE MENU

See Figure 3.9. The options available from the ***MODE*** menu are:



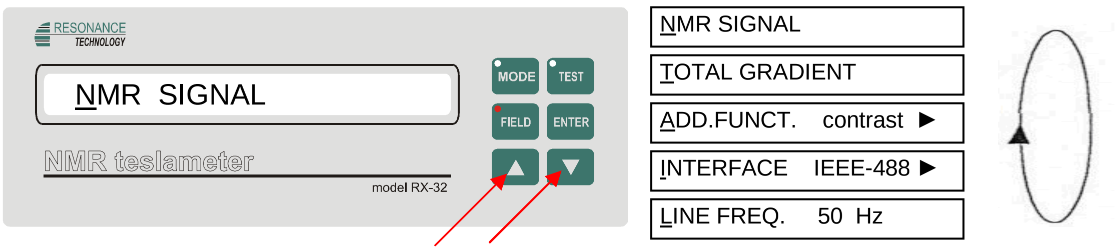
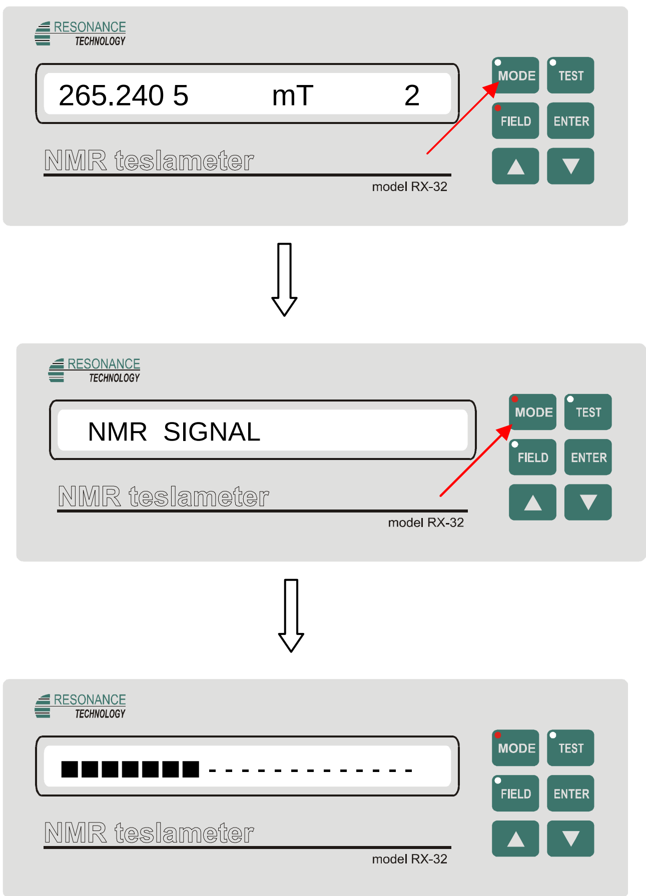


FIGURE 3.9 Options available from the mode menu

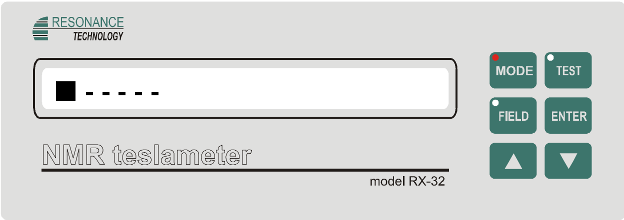
3.4.1. NMR SIGNAL

This option changes the normal digital readout to a bargraph indicating the relative amplitude of the NMR signal, shown in Fig. 3.10. The bargraph is a linear indication of signal amplitude. From one to nineteen blocks will appear on the left side of the display and one to nineteen dashes will appear on the right. The higher the NMR signal, the greater the number of blocks and dashes. Each dash counts as one unit, each block as 1 to 20 dashes. For instance for the "strong signal" display shown in Figure 3.10 the total value is (1x20)+(1x19)+(1x18) ...etc. blocks + 13 dashes = 132 units. Note that each block counts n dashes, where n means block position from the left These values are also available from the communications ports as a number not analog line (see Section 6.0).

As discussed in Section 2.0, the NMR signal amplitude is primarily a function of the field gradient over the volume of the sample material. The lower gradient the greater and narrower the NMR signal will be. This option is useful when attempting to quickly locate an area within a magnetic field that will yield reasonable measurements



STRONG SIGNAL = 132 units arbitrary



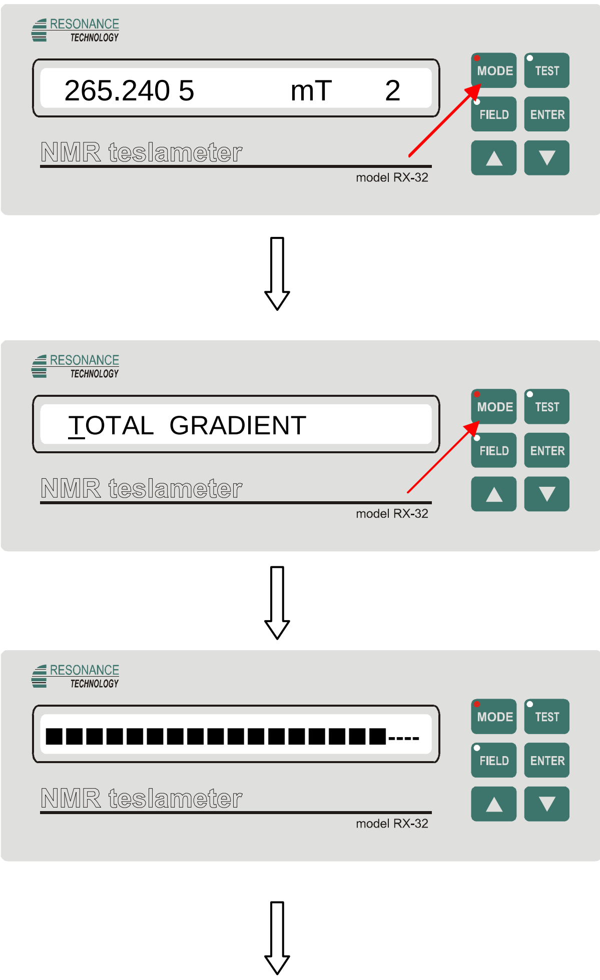
WEAK SIGNAL

FIGURE 3.10 NMR signal option

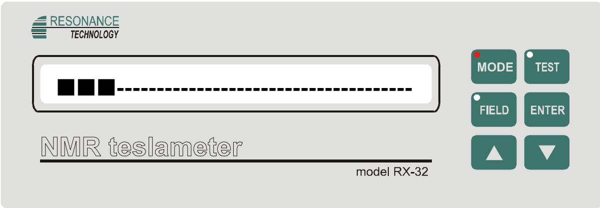
3.4.2. TOTAL GRADIENT

This option changes the normal digital readout to a bargraph indicating the total gradient of the magnetic field over the volume of the sample material, shown in Fig. 3.11. The bargraph is a nonlinear indication of total gradient. From one to twenty dashes will appear on the display. The higher the -gradient, the greater the number of dashes. Each group of twenty dashes will be replaced by one solid block starting on the left side of the display. Each dash counts as one unit. Starting from the left the first block counts as 20, the second as 19, the third as 18, etc. For instance the "good homogeneity" display shown in Fig. 3.11 has a total value of 20 + 19 + 18 + 10 = 67. These values are also available from the communications ports (See Section 6.0).

This option is useful when attempting to quickly locate an area within a magnetic field that has the best homogeneity or when attempting to improve field homogeneity with shim coils.



HIGH MAGNETIC FIELD GRADIENT



LOW MAGNETIC FIELD GRADIENT

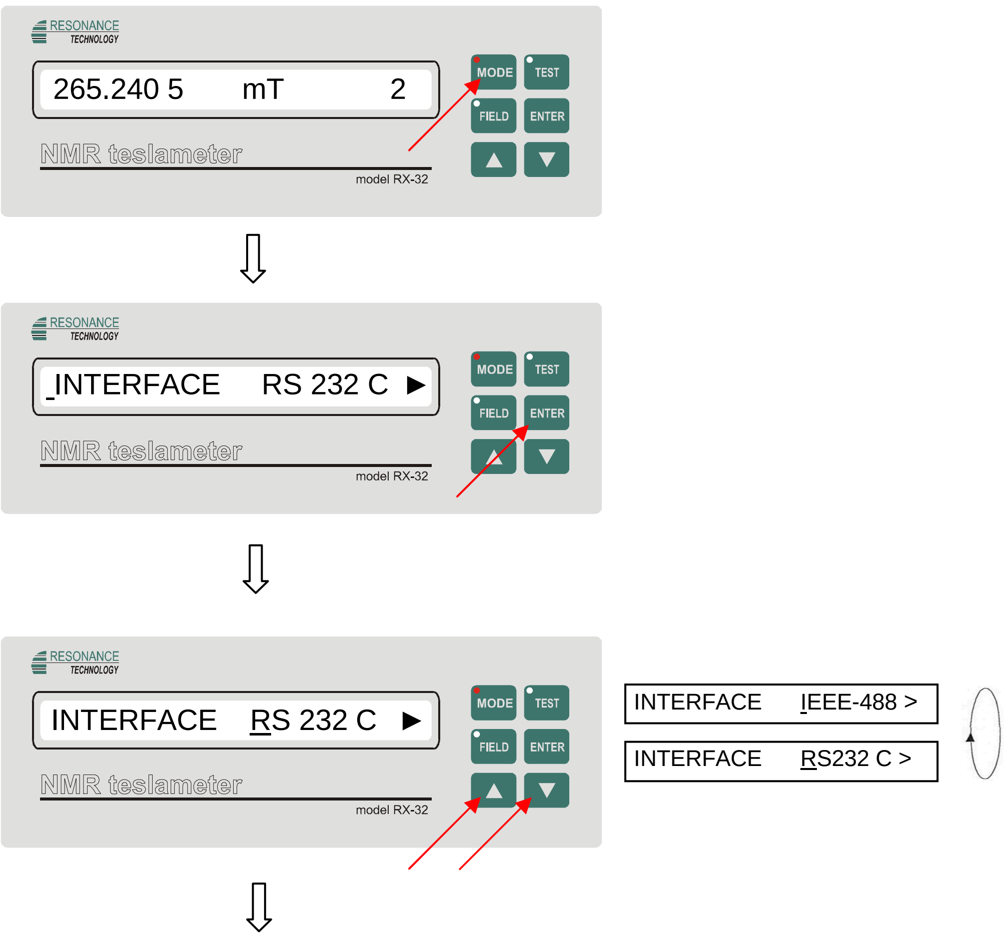
FIGURE 3.11 Relative gradient measure

3.4.3. INTERFACE

This allows you to change the operating characteristics of the IEEE-488 and RS-232 communications ports, as shown in Fig. 3.12 and 3.13, respectively. For the IEEE-488 interface only the primary address is programmable, from 00 - 30 decimal. For the RS-232 interface only the baud rate is programmable, either 2400, 4800, 9600 or 19200 baud. The other characteristics default to eight (8) data bits, no parity and one stop bit.

NOTE: Upon power-up the instrument will display either RS-232 **ON** or IEEE-488 **ON** to indicate which port is active. Only one port can be activated upon power-up and this is defined in ***SETUP #1*** in the ***SETUP SAVE/LOAD*** option in the **FIELD** menu (see Section 3.4.1). If you wish to change from one port to another, or if you wish to permanently change the IEEE-488 address or RS-232 baud rate you must do the following:

1) Select the ***INTERFACE*** option and select the desired port or change the desired parameter.
2) From the ***FIELD*** menu select the **SETUP *SAVE/LOAD*** option, select ***SAVE*** and select location *1.*
3) Turn the instrument **OFF**, then **ON** to activate the new port.



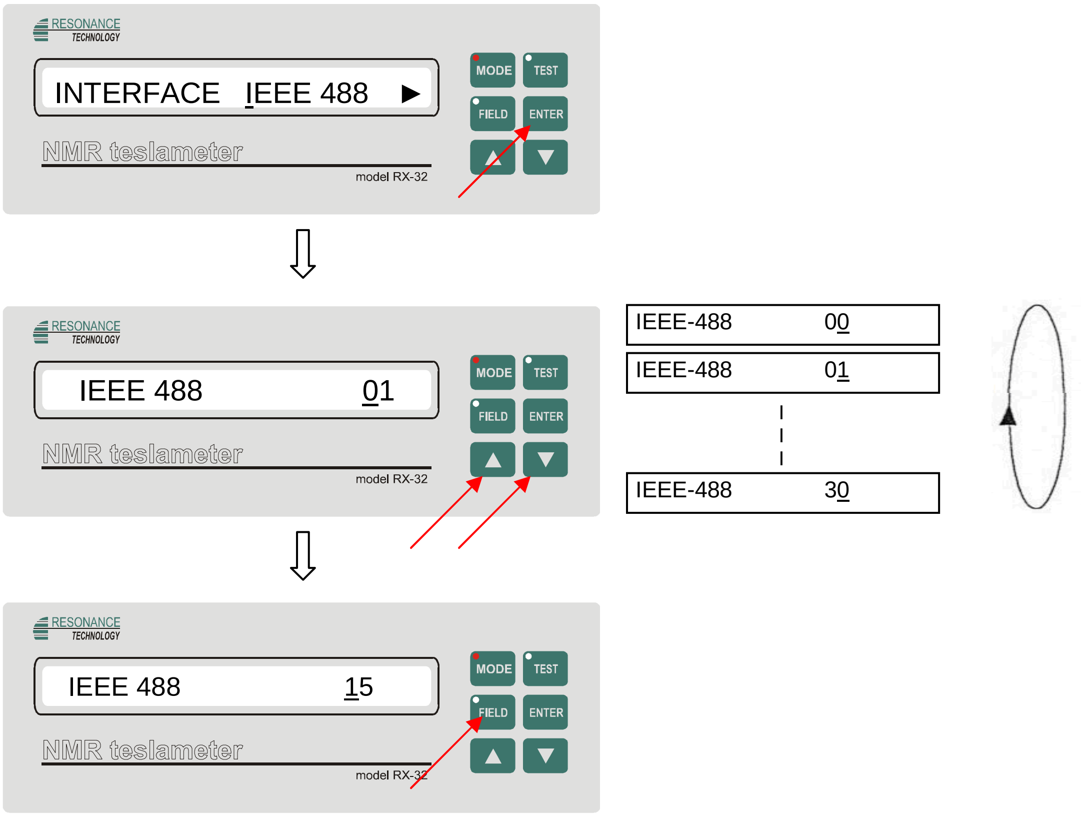
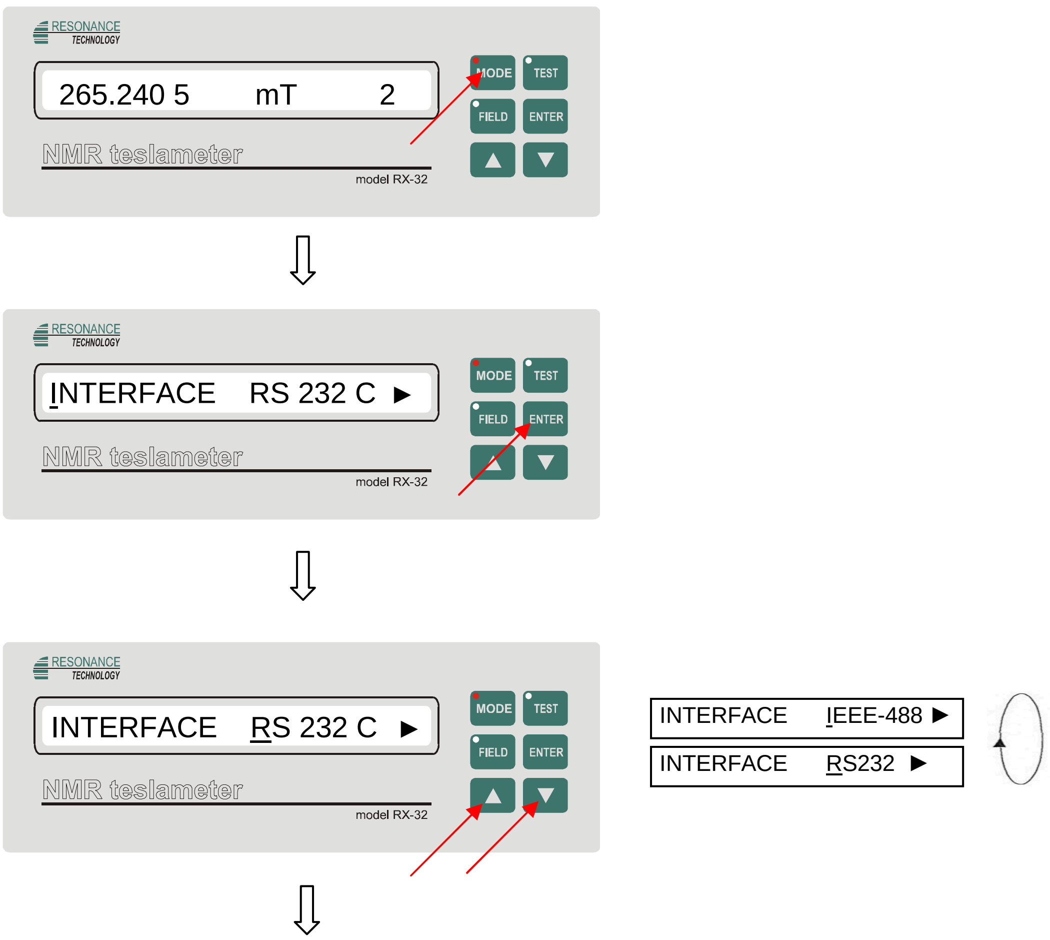


FIGURE 3.12 IEEE-488 comunications option



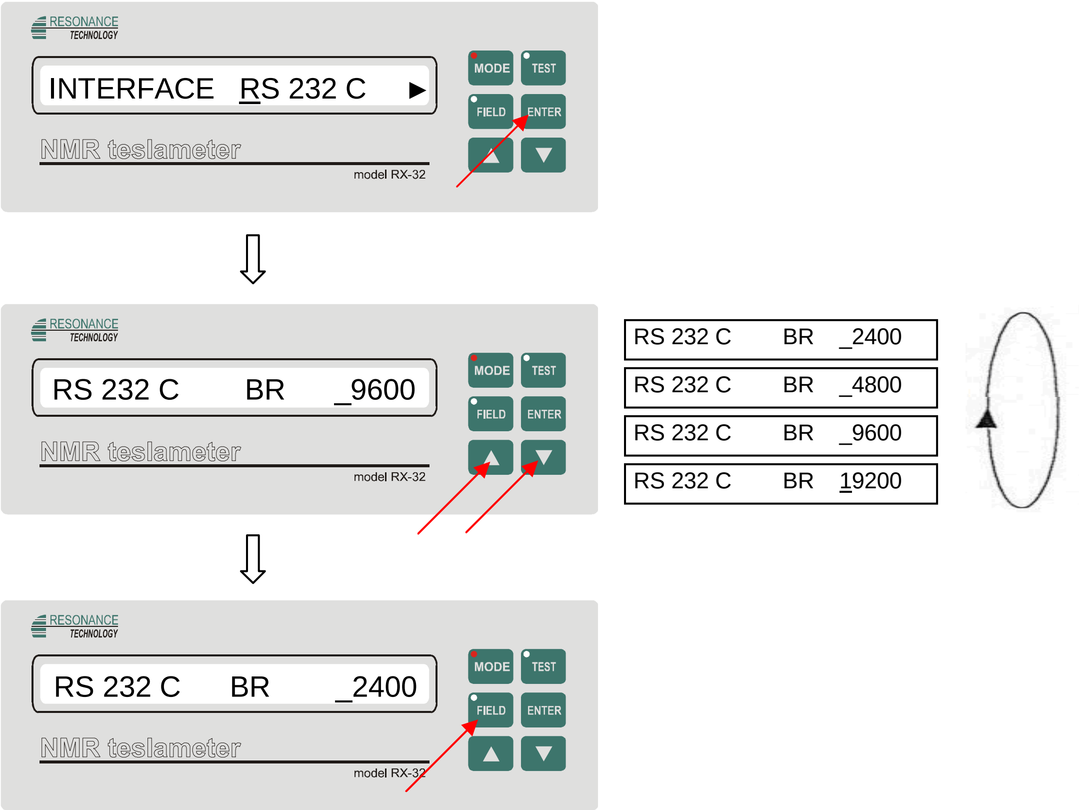
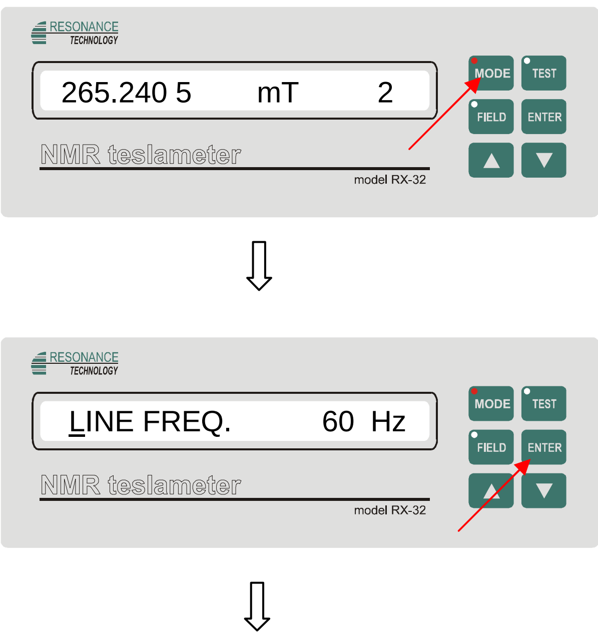


FIGURE 3.13 RS-232 comunications option

3.4.4. LINE FREQUENCY

Certain internal operations are synchronized to the line frequency of the 115/230 VAC service, either 50 Hz or 60 Hz., see Fig. 3.14.

NOTE: This option must be set correctly or measurement errors will occur. It is best to save this setting in ***SETUP #1*** of the ►option in the ***FIELD*** menu. The meter configures the instrument using ***SETUP #1*** every time it is powered up.



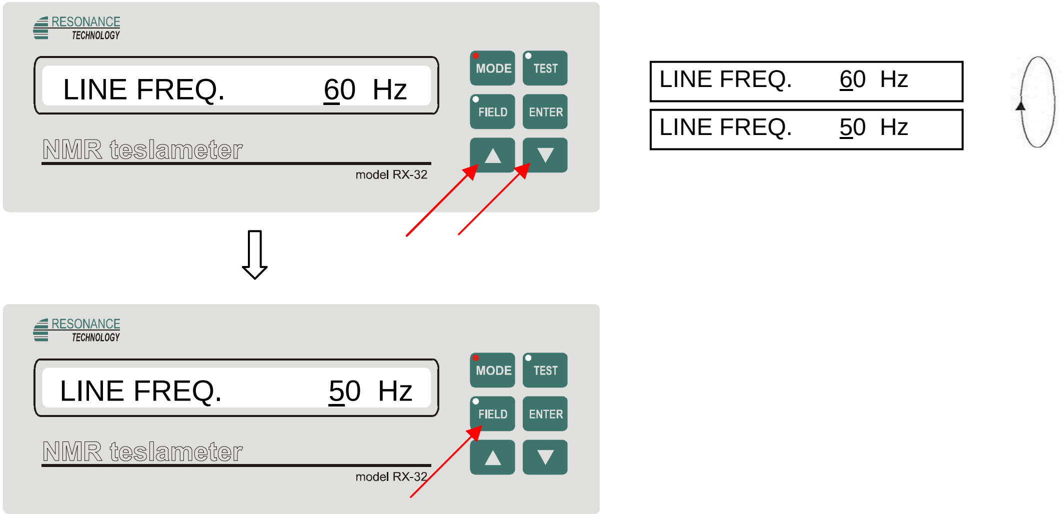


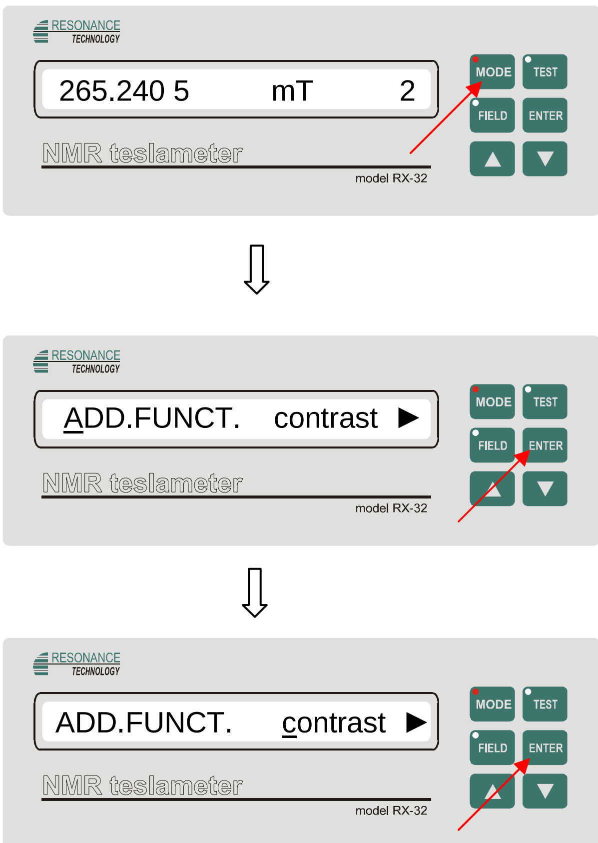
FIGURE 3.14 Line frequency option

3.4.5. ADDITIONAL FUNCTIONS

Certain additional functions are available from this option:

3.4.5.1. DISPLAY CONTRAST

The display's contrast can be adjusted to suit the ambient lighting conditions, as shown in Fig. 3.15. One of 30 settings are possible with the highest number representing the lightest contrast.



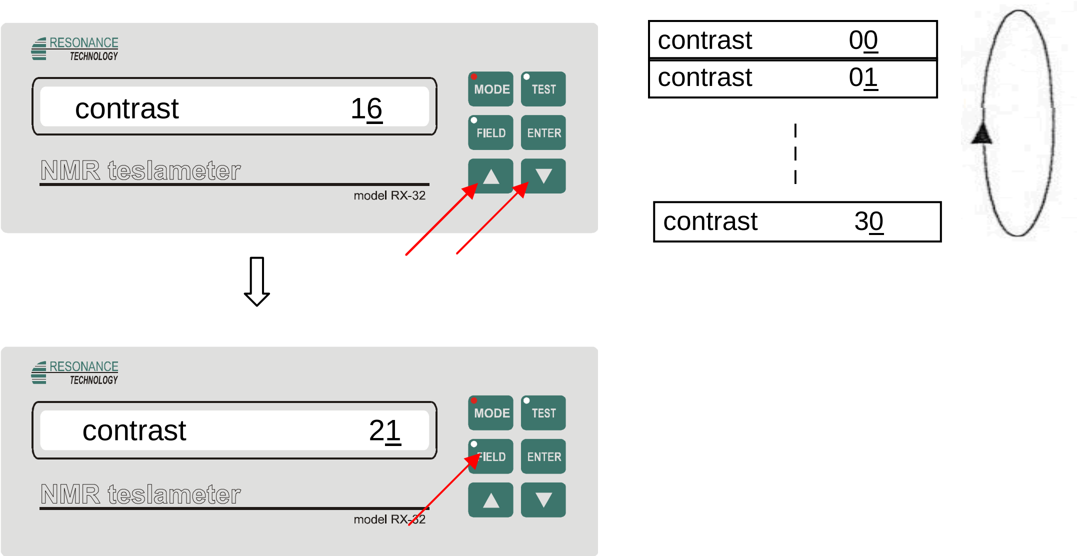


FIGURE 3.15 Display contrast option

3.4.5.2. ¥ COEFFICIENT

The physical constants relating to the nuclear magnetic resonant frequency of the electron, hydrogen and deuterium are programmed into the instrument's permanent memory. As shown in Fig. 3.16 these values can be viewed by selecting the γ *(gamma)* ***COEFF.*** option and selecting either ^{1}H , ^{2}*D*, or e respectively.You are not allowed to change these values.

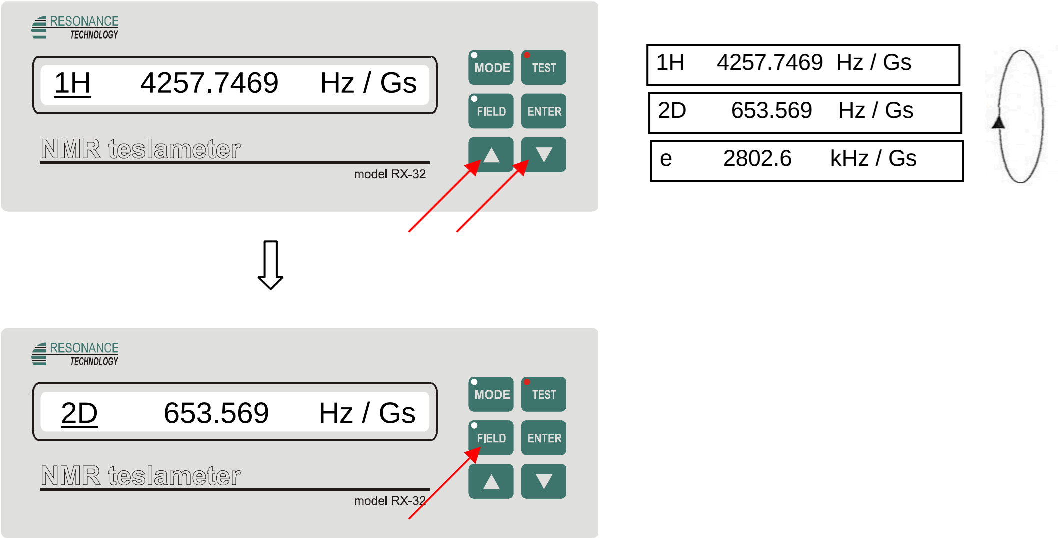
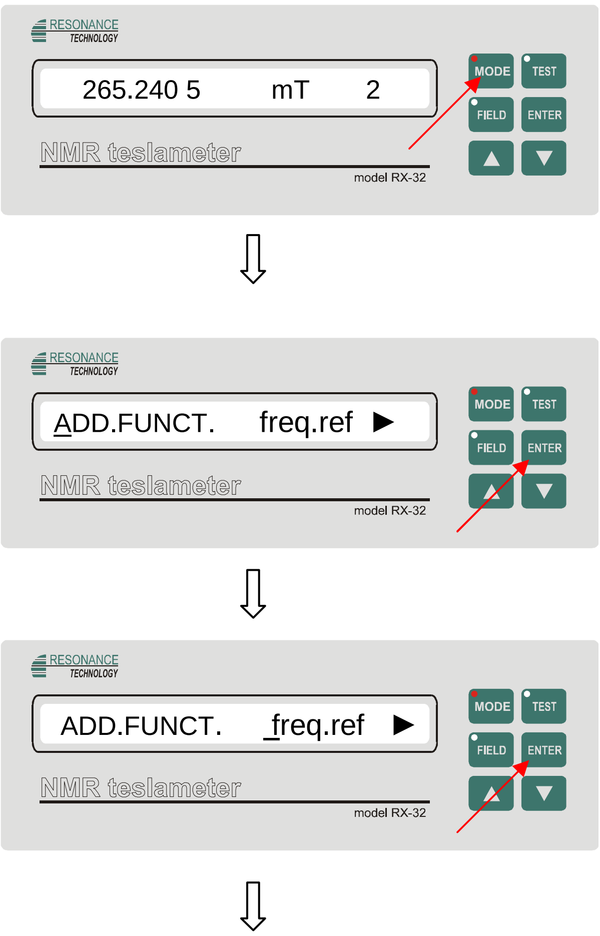


FIGURE 3.16 Y coefficient option

3.4.5.3. FREQUENCY REFERENCE (now inaccessible !)

The precision of the instrument is governed by a very precise internal **O**ven **C**ontrolled **X**-tal **O**scillator (OCXO). The operating frequency of this reference is programmed into the instrument's permanent memory. As shown in Fig. 3.17 this value can be viewed by selecting the *FREQ REF* option. You are not allowed to change this value.



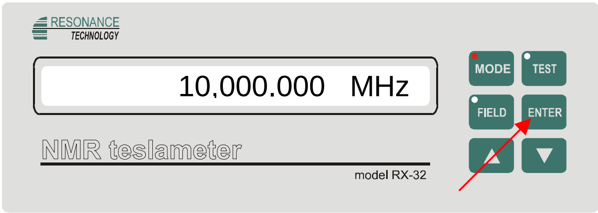


FIGURE 3.17 Frequency reference option

3.4.5.4. METER SERIAL NUMBER

The instrument's serial number appears on the back of the meter. It is also stored in the meter's permanent memory and can be viewed by selecting the *SER.NO* option, as shown in Fig 3.18. You are not allowed to change this value.

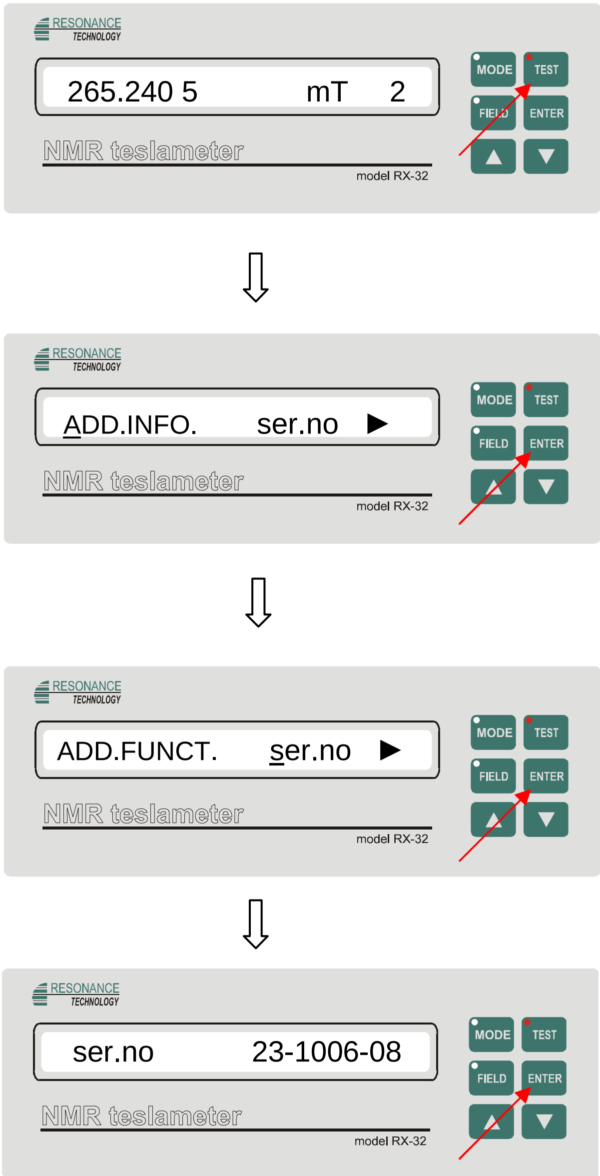


FIGURE 3.18 Serial number option

3.5. OPTIONS IN THE TEST MENU

See Fig. 3.19. The options available from the TEST menu are:

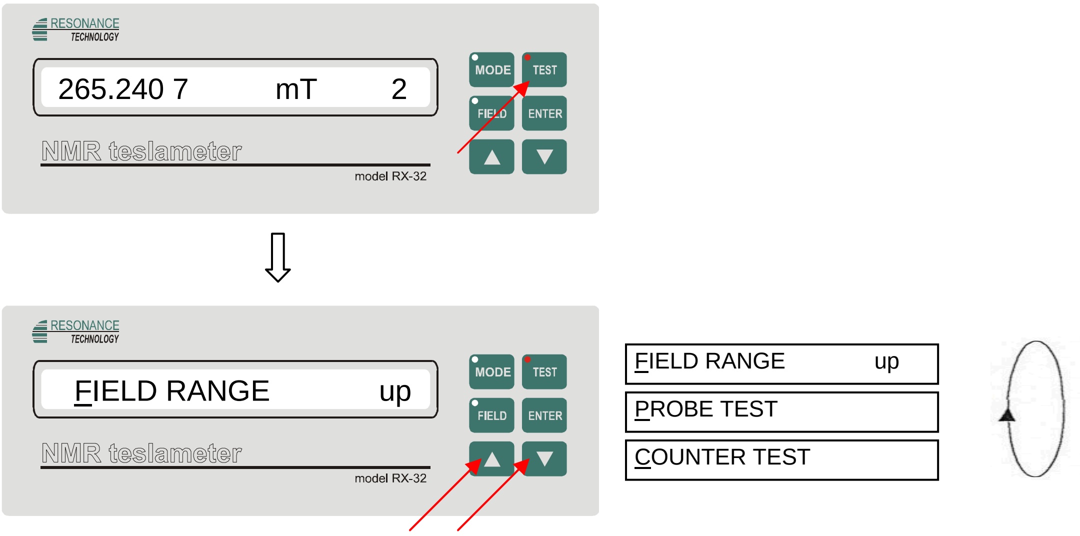


FIGURE 3.19 Options available from the test menu

3.5.1. COUNTER TEST

Used primarily for diagnostics and calibration this option allows a reference frequency to be injected into the NMR head connector and a reading to appear directly related to this signal (not available – for service using only).

3.5.2. PROBE TEST

This test determines the type of probe attached (Low, Middle or High Field). If no probe is attached a "CONNECT A PROBE" message will appear.

3.5.3. FIELD RANGE

The operating range of each probe tip is divided into seven (7) subranges. These ranges are unique to each probe/head combination and are not necessarily equal in span. For instance using the middle field probe, which has an overall range of 0.076 T –1.91 T (760 Gs -19.1 kGs) the first subrange might cover 0.076 T - 0.22 T (760 Gs - 2200 Gs) while the second subrange covers 0.20 T - 0.43 T (2000 Gs - 4300 Gs). This option allows you to know the span of each subrange, particularly useful when using the *MANUAL* range setting.To inspect the span of a particular range do the following:

1) From the *FIELD* menu select the *RANGING* option, select *MANUAL* and then select the range (1-7) you are interested in (see Section 3.4.3).

2) Follow the steps shown in Fig. 3.20. By selecting *DOWN* you can inspect the lower end of the span and *UP* to inspect the upper end of the span.

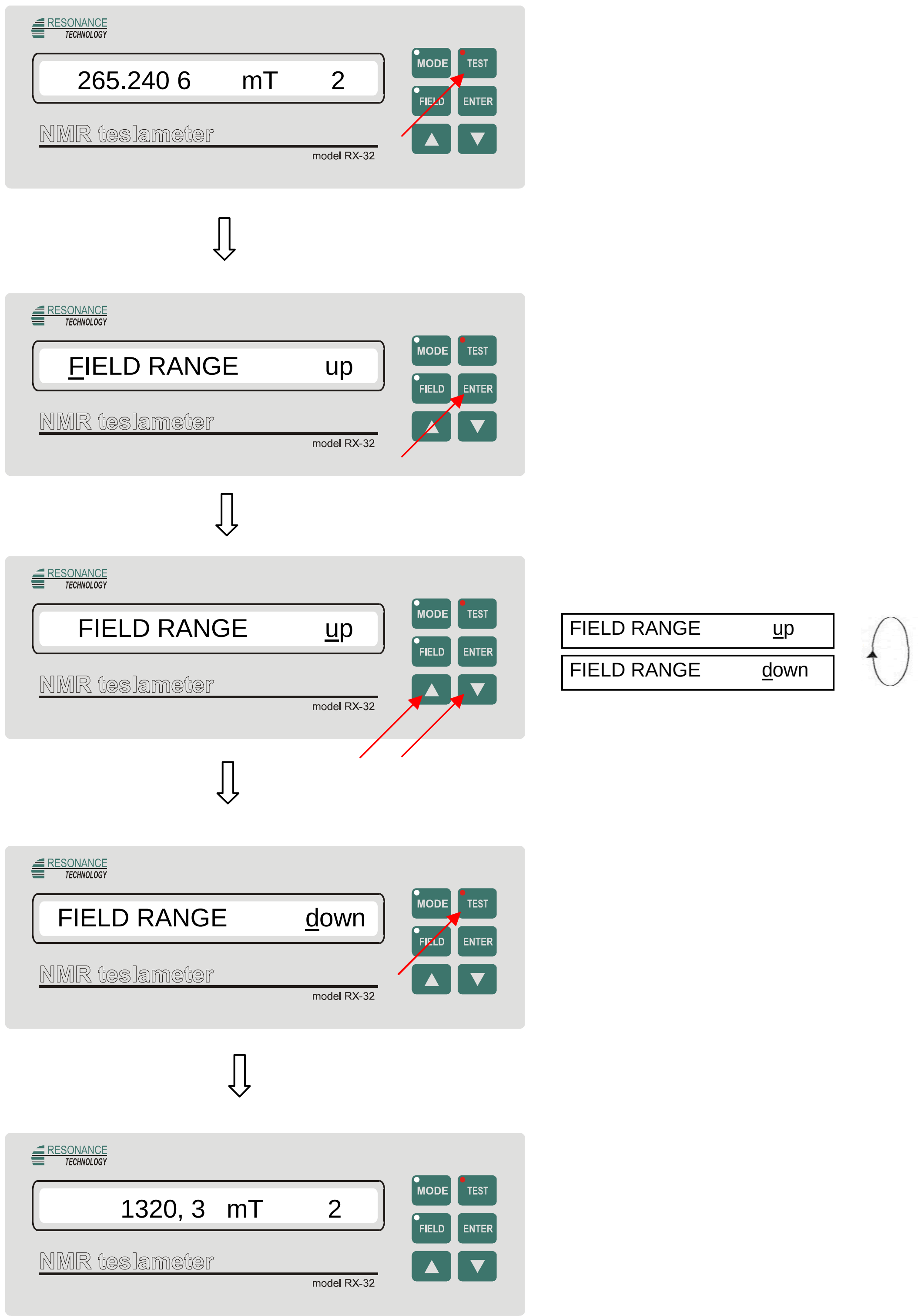


FIGURE 3.20 Field range option

Fig. 3.21 summarizes the programming sequences when configuring the instrument.

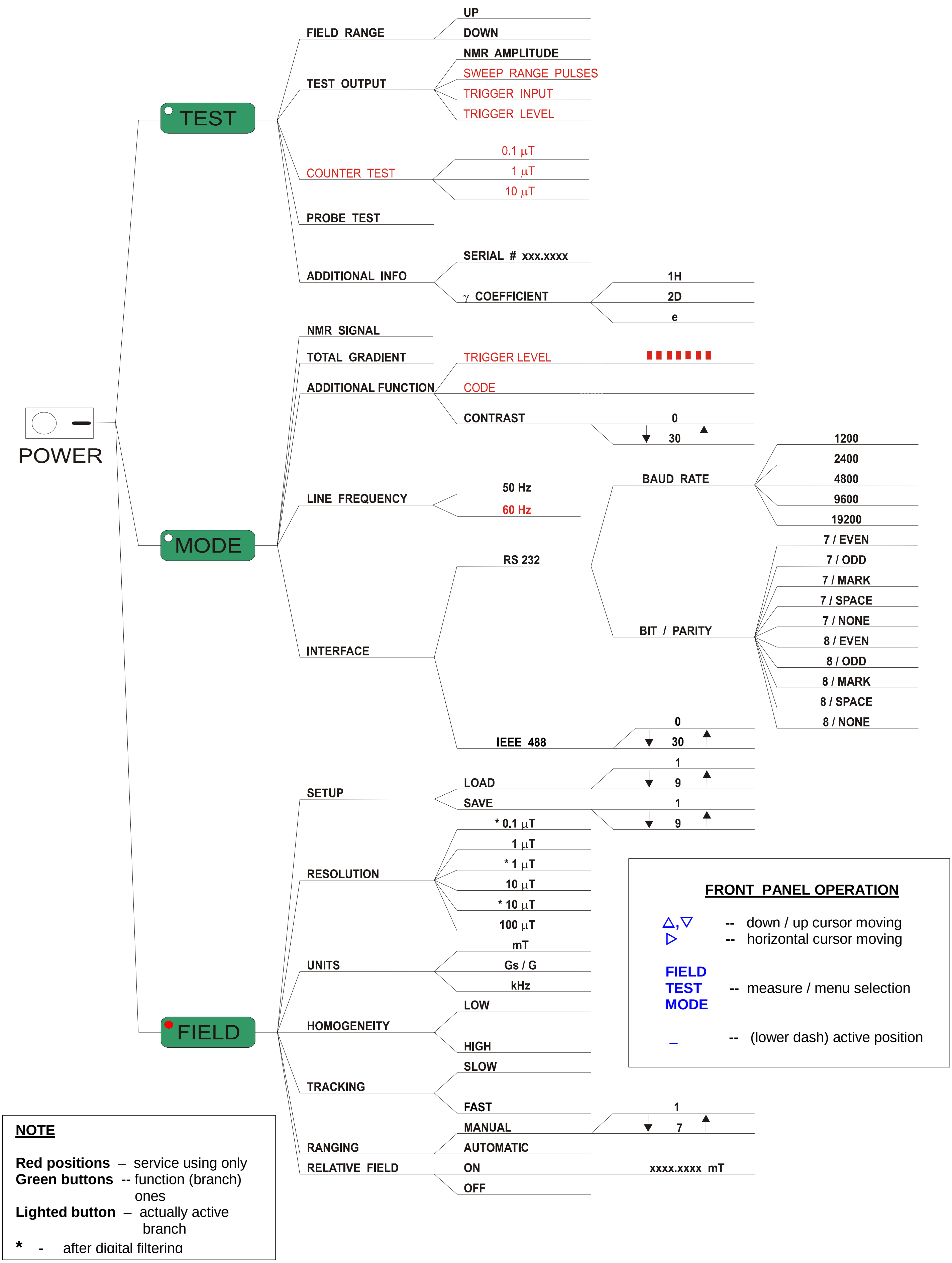


FIGURE 3.21 Teslameter menu

4.0 INSTRUMENT OPERATION

4.1. INITIAL INSTRUMENT SETTINGS

Section 3.0 explains how to configure the instrument according to your measurement needs. As mentioned in Section 3.4.1 there are nine permanent storage locations that can be used to save the way you have configured the instrument. Later you can recall one of these setups, instantly configuring the instrument without the need to manually program each parameter. Teslameter always uses SETUP #1 to configure itself upon power up.

4.2 LINE FREQUENCY OPERATION (50/60 Hz)

As mentioned in Section 3.5.4 the instrument uses the frequency of the line voltage to regulate some of its internal operations. Using the *LINE FREQUENCY* option in the *MODE* menu select either 50 Hz or 60 Hz to match your service or errors may result. It is best to save this in location #1 in the *SETUP SAVE/LOAD* option so that the instrument always powers up with the correct line frequency setting.

4.3. MANUAL RANGE OPERATION

If the present field level is outside of the *MANUAL* subrange you have selected the message

MF   OUT OF RANGE

will appear (the "MF" means middle field probe). This will be "LF" or "HF" if the low field or high field probe is used. Below this message a cursor will move back and forth, indicating the meter's attempt to search for a valid NMR signal. When a valid reading is displayed the right-most digit on the display will indicate the subrange that you selected.

4.4. AUTOMATIC RANGE SELECTION

As the instrument searches for a valid NMR signal the message AUTO SEARCH will appear. The right-most digit on the display indicates the subrange setting and will advance up or down while searching. When a valid reading is displayed this digit will indicate the subrange that was selected.Instrument will search through the entire set of subranges twice. If a valid NMR signal is not found the search will be terminated and the message

FIELD NOT MEASURABLE

will appear. This can be caused by the field level being below or above the range of the probe you are using. It can also be caused by high gradients of the field being measured. You may want to use the *NMR SIGNAL* and *TOTAL GRADIENT* options in the *MODE* menu (see Sections 3.5.1 and 3.5.2) to make this determination.To restart the automatic search process press the *FIELD* switch.

The speed at which the subranges are scanned is governed by the *TRACKING* speed. The up/down direction of the scan is determined by certain aspects of the NMR signal.
NOTE: AUTO range may not be used if the *HOMOGENEITY* option is set to *LOW.* If AUTO range is selected and you change to HOMOGENEITY *LOW a* warning will be issued and the instrument will reset to the *MANUAL* ranging mode.

4.5. DATA HOLD

You can temporarily freeze the displayed reading by pressing the *ENTER* switch. The right-most digit of the display will change to an "H" and the present reading will be held indefinitely or until:

1). the *ENTER* switch is pressed again or

2). the present field level moves outside of the present subrange.

A request for Data Hold will be ignored if the meter is searching through subranges in the *AUTO* mode, or if the present field level is outside of the subrange selected in the *MANUAL* mode.

4.6. POLARITY OF READING

The flux density is measured over the volume of the sample. The meter is insensitive to field polarity.

The reading will always be an unsigned value except when using the *RELATIVE* option (see Section 3.4.2).

4.7. WARNING MESSAGES

There are certain combinations of instrument settings that are illegal. However, rather than preventing you from making a measurement a warning message will appear and the instrument will reconfigure to remove the illegal combination. Continue to press the *FIELD* switch until all warning information has been presented.

4.7.1. WARNING (RESOLUTION)

This warning indicates one of two possible conflicts:

1) Between the *RESOLUTION* and the *HOMOGENEITY* settings (illegal combination is high *RESOLUTION* and low *HOMOGENEITY).*

2) Between the *RESOLUTION* and the *TRACKING* speed settings (illegal combination is high *RESOLUTION* and fast *TRACKING* speed).

In either case the instrument will select a *RESOLUTION* setting that will work.

4.7.2. WARNING (RANGING)

This warning indicates one of two possible conflicts;

1) Between the *RANGING* and *HOMOGENEITY* settings (illegal combination is auto *ranging* and low *homogeneity).*

2) If using the low field probe and selecting auto *RANGING* (the LF probe only uses the lowest subrange).In either case the instrument will select the *MANUAL* mode.

4.7.3. WARNING (RELATIVE)

This warning indicates that the *RELATIVE* mode was turned on with the *UNITS* option set for hertz (kHz). The *RELATIVE* value can only be specified in gauss or tesla units. In this case the *RELATIVE* mode will be turned off.

4.8. MEASURING HINTS

4.8.1. USE OF AUTOMATIC RANGE SELECTION

Automatic range selection is primarily intended to measure the flux density of an unknown static magnetic field or that of a known but slowly changing field. Allow the instrument time to scan through the subranges several times. The inability of the instrument to locate a valid NMR signal indicates that the field may be below or above the range of the probe, may be changing too fast or may contain excessive gradients or noise. If this occurs try reducing the *RESOLUTION* and/or the *TRACKING rate.* As a last resort use the *MANUAL ranging* mode, select *LOW HOMOGENEITY and* manually select various ranges.

In some applications the approximate flux density of the field to be measured may already be known. If you do not expect this level to vary by more than the span of one subrange use the *MANUAL* mode. If you expect the probe to be occasionally removed from this known field and back again, continue to use the *MANUAL ranging* mode. In both cases the speed at which the NMR locates a valid NMR signal will be much faster than with the *AUTOMATIC* range selection.

4.8.2. USE OF NMR SIGNAL AND TOTAL GRADIENT OPTIONS

The *NMR SIGNAL* and *TOTAL GRADIENT* options (see Sections 3.5.1 and 3.5.2) can be used to determine the quality of the field to be measured. If the instrument is having problems locating a valid NMR signal these options might provide a clue to the reason. Even fields with overall poor quality may contain points where the homogeneity is very good. These areas can be located using these options before you obtain a quantitative value for the field. Though *AUTOMATIC* range selection works in these modes you may find it best to use the *MANUAL* ranging option and set the *HOMOGENEITY* to *LOW.*

5.0 COMMUNICATIONS PORTS

5.1. PORT SELECTION

Before using one of the communications ports it must be activated using the *INTERFACE* option in the MODE menu. See Section 3.4.3. It is best to save this setting in location #1 in the *SETUP SAVEA.OAD* option so that the instrument always powers up with the correct port setting. When the instrument powers up the message RS-232 ON or IEEE-488 ON will appear, indicating which port is active.

5.2. IEEE-488 PORT CONNECTOR

Fig. 5.0 depicts the IEEE-488 port connector, which is common to many test and measurement instruments. Up to 15 instruments can be connected to a common bus in a "daisy chain" fashion. The bus is normally controlled by computer but another device can control the bus if allowed to and capable of doing so. Each instrument is assigned a unique identity code or address. The RX-32 address is assigned using the *INTERFACE* option in the *MODE* menu. See Section 3.4.3

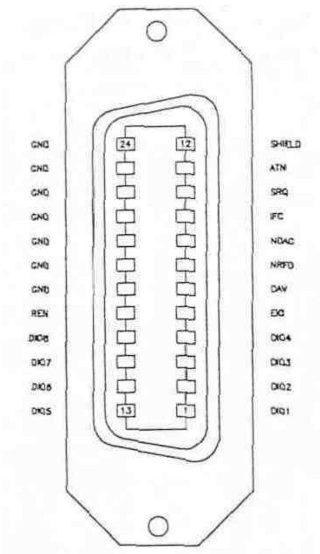


FIGURE 5.0 IEEE 488 port connection

5.3. RS-232 PORT CONNECTOR

Figure 5.1 depicts the RS-232 connector, which supports only the transmit and receive lines. Hardware handshaking is not supported. Also shown are two interface cable connections that can be used to interface to personal computers with 9-pin or 25-pin "D" type connectors. Cable length should be limited to 12' (3.6 m).

The only serial characteristic that is programmable by the user is the baud rate, either 2400, 4800, 9600 or 19200 baud, using the *INTERFACE* option in the *MODE* menu. See Section 3.4.3. The remaining characteristics default to no parity, one (1) stop bit and eight (8) data bits.

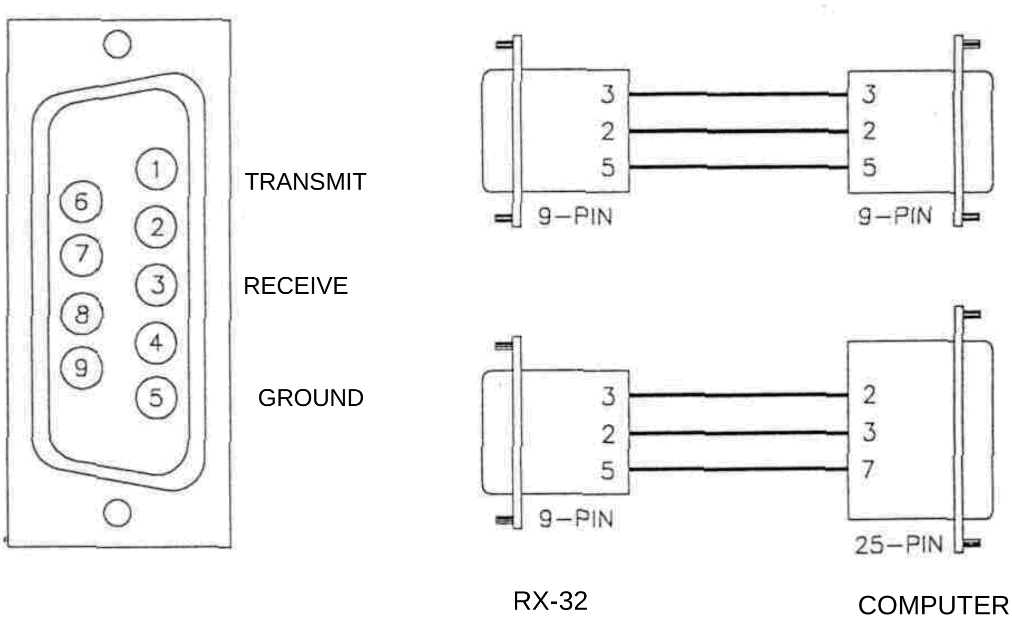


FIGURE 5.1 RS 232 port configuration

6.0 REMOTE PROGRAMMING

6.1. OVERVIEW

Many of the configuration options that can be modified from the front panel can be changed by a remote device via the communications ports. The remote device, generally a computer, can also acquire field measurements from the meter.

The RX-32 is programmed by sending ASCII commands strings consisting of several characters. Most of these commands are the same for IEEE-488 and RS-232, but because the ports operate differently, each will be discussed separately.

6.2. PROGRAMMING COMMANDS via RS-232

A serial port command consists of several ASCII characters terminated by a carriage return <cr> character. In most cases the meter will respond by sending one or more characters back to the remote device,, also terminated by the carriage return <cr> character.

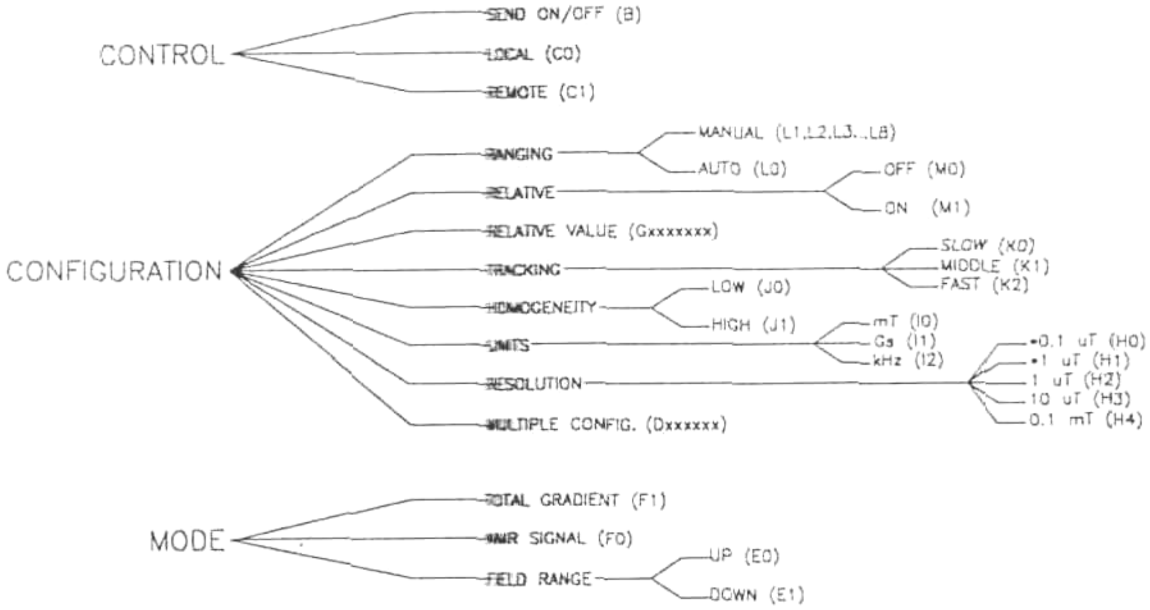


FIGURE 6.0 RS-232 command tree

6.2.1. CONFIGURATION COMMANDS

The following commands will allow you to change the configuration options described in Section 3.4. The meter will only accept these commands if it has been placed in the *REMOTE* mode. Section 6.2.5.2 discusses how to do this.

6.2.1.1. HOMOGENEITY COMMAND Jx<cr>

Select the desired *HOMOGENEITY* level by the commands:

J0<cr> for LOW homogeneity, J1<cr> for HIGH homogeneity

6.2.1.2. UNITS COMMAND Ix<cr>

Select the desired *UNITS* of measure by the commands:

I0<cr> for militesla (mT), I1<cr> for gauss (Gs), I2<cr> for kilohertz (kHz)

6.2.1.3 RESOLUTION COMMAND Hx<cr>

Select the desired *RESOLUTION* and filtering with the commands: H0<cr> for 1µ T /10mG /0.01kHz, filter ON; H1<c> for 1uT/10mG /0.01kHz, filter OFF; H2<cr> for 0.1 µT / 1 mG / 0.001 kHz, filter ON; H3<cr> for 10µT /100 mG / 0.1 kHz, filter OFF; H4<cr> for 100 µT /1 G /1kHz.

6.2.1.4. RELATIVE ON/OFF COMMAND Mx<cr>

Turn the *RELATIVE* mode ON or OFF by the commands:

M0<cr> for OFF; M1<cr> for ON

6.2.1.5. RELATIVE VALUE COMMAND Gxxxxxxx<cr>

This command sets a seven-digit *RELATIVE* value by the command:

Gxxxxxxx<cr>

Note that the seven-digit value does not contain a decimal point. The position of the decimal point depends on the selected units of measurement and will be xxxx.xxx mT or xxxxx.xx Gs (the *RELATIVE* mode can not be used when the units have been set for kHz). Also note that this command only sets the relative value but does not engage or deactivate the *RELATIVE* mode. Use the M<cr> command for this.

.

6.2.1.6. TRACKING COMMAND Kx<cr>

Select the desired *TRACKING* speed by the commands:

K0<cr> for SLOW, K1<cr> for MIDDLE , K2<cr> for FAST

6.2.1.7. RANGING COMMAND Lx<cr->

Select the desired *RANGING* mode and subrange by the commands:

L0<cr>	for AUTOMATIC
L1<cr>	for MANUAL, subrange 1
L2<cr>	for “ , subrange 2
L3<cr>	for “ , subrange 3
L4<cr>	for “ , subrange 4
L5<cr>	for “ , subrange 5
L6<cr>	for “ , subrange 6
L7<cr>	for “ , subrange 7

6.2.1.8. MULTIPLE CONFIGURATION COMMAND Dxxxxxx<cr>

This command allows multiple options to be set with one command:

D[resolution][units][homogeneity][tracking][ranging][relative]<cr>

resolution:	0 for 1 µT /10mG /0.01kHz, filter ON , 1 for 1µT /10mG /0.01kHz, filter OFF, 2 for 0.1 µT /1 mG / 0.001 kHz, filter ON, 3 for 10 µT /100 mG / 0.1 kHz, filter OFF, 4 for 100 µT/1Gs /1kHz, filter OFF,
units:	0 for militesla (mT) 1 for gauss (Gs) 2 for kilohertz (kHz)
homogeneity:	0 for LOW homogeneity 1 for HIGH homogeneity
tracking:	0 for SLOW 2 for FAST
ranging:	0 for AUTOMATIC 1 for MANUAL, subrange 1 2 for “ , subrange 2 3 for “ , subrange 3 4 for “ , subrange 4

	5 for	"	, subrange 5
	6 for	"	, subrange 6
	7 for	"	, subrange 7
relative:	0 for OFF		
	1 for ON		

EXAMPLE: The command D301000<cr> selects a resolution of 10 µT, units in mT, high homogeneity, slow tracking, automatic range selection and the relative mode turned OFF.

6.2.2. RESPONSE TO CONFIGURATION COMMANDS

For the configuration commands described in the previous section the meter will send back one or more response characters immediately following the command:

6.2.2.1. NORMAL RESPONSE D<cr>

This response indicates that the command was accepted and instrument was modified as requested.

6.2.2.2. WARNING RESPONSE Dxxxxx<cr>

This response indicates that the command was accepted and the instrument was modified as requested, but the request caused an illegal combination of options to be set (see Section 4.7). In this case other options had to be changed in order to remove the violation. The response indicates the changes that were made, as follows;

D10000<cr> = *RELATIVE* mode has been turned OFF.

D01000<cr> = change in *TRACKING* setting.

D00100<cr> = *RANGING* option was changed to *MANUAL*.

D00010<cr> = subrange selection was changed. D00001<cr> = *RESOLUTION* setting was changed.

More than one indication can be set at one time, depending on the situation.

6.2.2.3. ERROR RESPONSE Exx<cr->

This response indicates a problem with the command string.
The xx is a two-digit error code: E01 <cr> = the command contained too few or too many characters.
E02<cr> = the command is not defined or a command was issued while the meter was in the *LOCAL* mode

6.2.3. MODE SELECTION COMMANDS

These commands allow you to access the *TOTAL GRADIENT, NMR SIGNAL* or *FIELD RANGE* modes discussed in Sections 3.5 and 3.6.

NOTE: To return to the normal flux density measurement mode issues one of the configuration commands, such as UNITS, TRACKING, etc.

NOTE: The meter does not send a response back to these commands.

6.2.3.1. MODE SELECTION COMMAND Fx<cr>

The *TOTAL GRADIENT* or *NMR SIGNAL* modes, described in Section 3.5, can be by the commands;
F0<cr> for NMR SIGNAL, F1<cr> for GRADIENT
These commands change the digital readout format to the bargraph formats discussed in Sections 3.5.1 and 3.5.2.

6.2.3.2. TEST MODE COMMAND Ex<cr>

The *FIELD RANGE* test mode, as described in Section 3.6.3, allows you to inspect the lower and upper boundary of each subrange. The commands are:
E0<cr> for FIELD UP, E1<cr> for FIELD DOWN
You should first select the subrange of interest using the Lx<cr> command.

6.2.4. RETURNED MEASUREMENT VALUES

Depending upon the present measurement mode the meter wiil transmit values for flux density, nmr signal or total gradient, as follows.

NOTE: The meter will only transmit this information if it has been instructed to do so via the *SEND ON/OFF* command. See Section 6.2.5.1.

6.2.4.1. FLUX DENSITY READINGS Vsxxxxxxx.xxx yyy<cr>

When the meter has been programmed to display normal flux density readings the value transmitted will consist of the "V" character followed by a sign, a 10-digit decimal value and a units indicator.

With the *RELATIVE* mode turned off the sign (s) character will be an ASCII space character. With the *RELATIVE* mode turned on the sign (s) character will be an ASCII minus (-) or plus (+) character.

The units indicator (yyy) will either be "mT", "Gs" or "kHz", depending on the *UNITS* that have been selected.

The decimal field value (xxxxxxx.xxx) will vary with the *RESOLUTION* selected and includes an ASCII decimal point (.):

RESOLUTION	UNITS = mT	UNITS = Gs	UNITS = kHz
0.1 uT	000246.3478 mT	0002463.478 Gs	not allowed
1 uT	000246.3478 mT	0002463.478 Gs	0010493.334kHz
10 uT	0000246.348 mT	00002463.48 Gs	00010493.33kHz
0.1 mT	00000246.35 mT	000002463.5 Gs	000010493.3kHz

NOTE: When in the *FIELD RANGE* test mode (Section 6.2.3.2) the meter's transmission will be the same as described above, but only for the 0.1mT resolution regardless of which resolution is presently selected. If the present *UNITS* is set to kHz it will be changed to mT.

UNITS = mT	UNITS = Gs	UNITS = kHz
00000246.35 mT	000002463.5 Gs	not allowed

6.2.4.2. TOTAL GRADIENT INDICATION Gxxx<cr>

When in the *TOTAL GRADIENT* mode the meter transmits a 3-digit qualitative value for total gradient ranging from 0 - 255, as explained in Section 3.5.2.

6.2.4.3. NMR SIGNAL INDICATION Sxxx<cr>

When in the *NMR SIGNAL* mode the meter transmits a 3-digit qualitative value for signal strength ranging from 0 - 255, as explained in Section 3.5.1

6.2.4.4. OUT OF RANGE INDICATION A<cr>

This transmission indicates that the present field level is outside of the selected subrange in *MANUAL RANGING* mode or outside the range of the probe in the *AUTOMATIC RANGING* mode. See Section 4.0 for information on over/under range conditions. When the meter is in this state it does not transmit readings on a continuous basis and will only transmit the A<cr> once. See Section 6.2.6 for more information.

6.2.5 CONTROL COMMANDS

There are two commands that control incoming reception and outgoing transmission:

6.2.5.1. SEND ON/OFF B<cr>

Upon power up the meter transmits flux density readings, as described in Section 6.2.4, on a continuous basis. This allows a computer to acquire readings without the need to send commands to or poll the meter. In some instances this may be disruptive to the user's program, possibly causing communication buffer overflows and slowing the system down if the incoming data generates system interrupts. The "B" command toggles the transmission on and off.

NOTE: The meter does not send back a response to this command.

6.2.5.2. LOCAL/REMOTE COMMAND Cx<cr>

When the instrument is in the *LOCAL* mode the instrument can be configured from the keypad. A remote device can obtain measurements from the port but can not change instrument settings. In the *REMOTE* mode the keypad is locked out and the remote device can obtain field measurements as well as change the instrument's settings. The only exception to this is the *SEND ON/OFF* command, which the meter will respond to in either mode. The commands are:

C0<cr> for LOCAL mode, C1<cr> for REMOTE mode

When in the *REMOTE* mode the "R" character will appear in the rightmost digit of the display.

NOTE: The meter does not send back a response to this command.

6.2.6. PROGRAMMING HINTS

1). If the meter is allowed to transmit readings on a continuous basis and a configuration command is issued the meter will respond and then resume normal transmissions. By the time you read your input buffer the contents could look like this:

V 000246.3478 mT<cr> V 000246.3478 mT<cr> D<cr>V 000246.3478 mT<cr>..

Notice the response D<cr> embedded in the string. Example #2 that follows demonstrates how to handle this situation but if this proves to be difficult you may want to use the B<cr> command to turn off the continuous transmission, configure the meter and then turn the continuous transmission back on.

2). Many computers automatically buffer incoming serial data. When you input from the serial port you are actually taking data from the buffer, not directly from the port. Keep this in mind when using the B<cr> command to turn off the continuous transmission. Your buffer may still be filled with characters from previous transmissions. It is best to clear this buffer prior to issuing the next commands.

3). If the meter is in an over/under range condition it will not transmit readings in any mode, and it does not transmit the A<cr> response on a continuous basis. The only way to determine this condition is to turn on the continuous transmission mode with the B<cr> command and then send a configuration command. The meter will respond normally to the command (such as D<cr>) and then transmit one A<cr">.