SECTION 4

GENERAL THEORY OF OPERATION

4-1. GENERAL

4-2. The EIP 371 Source Locking Microwave Counter automatically measures and displays the frequency of any CW signal from 20 Hz to 18.0 GHz. This frequency coverage is obtained in three bands: 20 Hz - 300 MHz (Band I), 100 MHz - 850 MHz (Band II), and 825 - 18 GHz (Band III). In addition, the 371 has the capability of locking a frequency modulatable source to any 100 kHz increment between 10 MHz and 18 GHz.

4-3. Measurements in Band I are made directly with a 300 MHz counter. This band is further divided into two channels: Channel A covers the 20 Hz - 135 MHz range with an input impedance of 1 megohm shunted by 20 pf. Channel B covers the 10 MHz - 300 MHz range with a 50 ohm input impedance.

4-4. Band II contains a prescaler which divides the input frequency by four. It operates over the frequency range of 100 MHz - 850 MHz with 50 ohm input impedance.

4-5. Band III covers the microwave frequencies from 825 MHz - 18 GHz with a 50 ohm input impedance. In this band, an Autohet Converter translates the input frequency downward into the frequency range of the 300 MHz Direct Counter. This is accomplished by mixing the input signal with a single known harmonic of the counter time base oscillator, to produce a difference frequency which can be counted directly. The frequency of the known harmonic is added to the counted signal to obtain the input frequency.

4-6. Figure 4-1 shows a block diagram of the complete 371 Counter. Figure 4-2 shows a block diagram of the Autohet Converter. Detailed theory and circuit descriptions of the Counter and Converter subassemblies are given in Section 9.

4-7. The operation of the 371 Counter is best described by separating the instrument into three distinct functions: the Direct Counter, the Autohet Converter, and the Lockbox circuitry. The Direct Counter and the Autohet Converter are interconnected in two significant areas: (1) presetting the counter to the appropriate harmonic number, and (2) counting the heterodyned difference frequency from the Converter by the Direct Counter.

4-8. 300 MHz DIRECT COUNTER

4-9. The measurement of frequency by the direct counter is accomplished by accumulating the number of input events (e.g: cycles of a sine wave), which occur within a precisely determined time interval. This time interval is based on the frequency of the Time Base Oscillator.

4-10. The 20 Hz - 300 MHz portion of the counter is separated physically into a number of subassemblies, designated A101 through A111 (refer to Figure 4-1, Block Diagram). The subassemblies are tied together via the Counter Interconnect Board A113. The counter is divided functionally in approximately the same manner as it is divided into subassemblies. Count Chain Boards A101, A102, and A103, operate functionally as a single unit, as do Control Boards A104 and A105. The principal interconnections between the units are shown in Figure 4-1.

4-11. Band I (20 Hz - 300 MHz) input has two operating modes. Band IA covers the 20 Hz - 135 MHz range, with 1 megohm/20 pf input impedance and 25 mV rms sensitivity. Band IB (10 MHz - 300 MHz) has a 50 ohm input impedance and -20 dBm sensitivity. Both Band IA and IB input signals are routed through Preamplifier A111, which contains an impedance converter section and a signal amplifier to drive the High Frequency board (A106).

4-12. The Band II (100 MHz - 850 MHz) input drives the Prescaler (A109), which divides the incoming frequency by four and routes it to the High Frequency Board.

4-13. The signal input to Band III (825 MHz - 18.0 GHz) is translated by the Autohet Converter into the range of 25 MHz - 275 MHz, and routed to the High Frequency board (A106).

4-14. The outputs of these three input signal processors thus fall between 20 Hz and 300 MHz; the frequency range of the direct counter. The individual assemblies which comprise the direct counter are described in general terms below, and in detail in Section 9.

4-15. The High Frequency Board (A106) receives the input signal from one of the processors, squares the signal, and forms it into a train of constant duration pulses. This pulse train frequency is then divided by ten, and sent to the Count Chain.

4-16. The Control 1 and Control 2 Boards (A104 and A105), contain circuitry to guide the counter through the steps necessary to acquire and display the input frequency. The circuits control the opening and closing of the signal gate in the High Frequency Board, and accept programming commands from the Converter, front panel controls (TEST, RESET, SAMPLE RATE), and the Remote Programming options.

4-17. The Count Chain Boards (A101, A102, and A103), accumulate the frequency from the High Frequency Board, store the accumulated information, and multiplex the stored information into a form usable by the Display Board (A110), which provides a visual display of the input frequency to the counter.

4-18. Reference Oscillator Buffer A108, produces a time base reference signal from either an internal 10 MHz oscillator, or an external 10 MHz source. All input frequencies to the counter are measured with respect to this signal.

4-19. The Power Supply (A107) provides regulated +12,

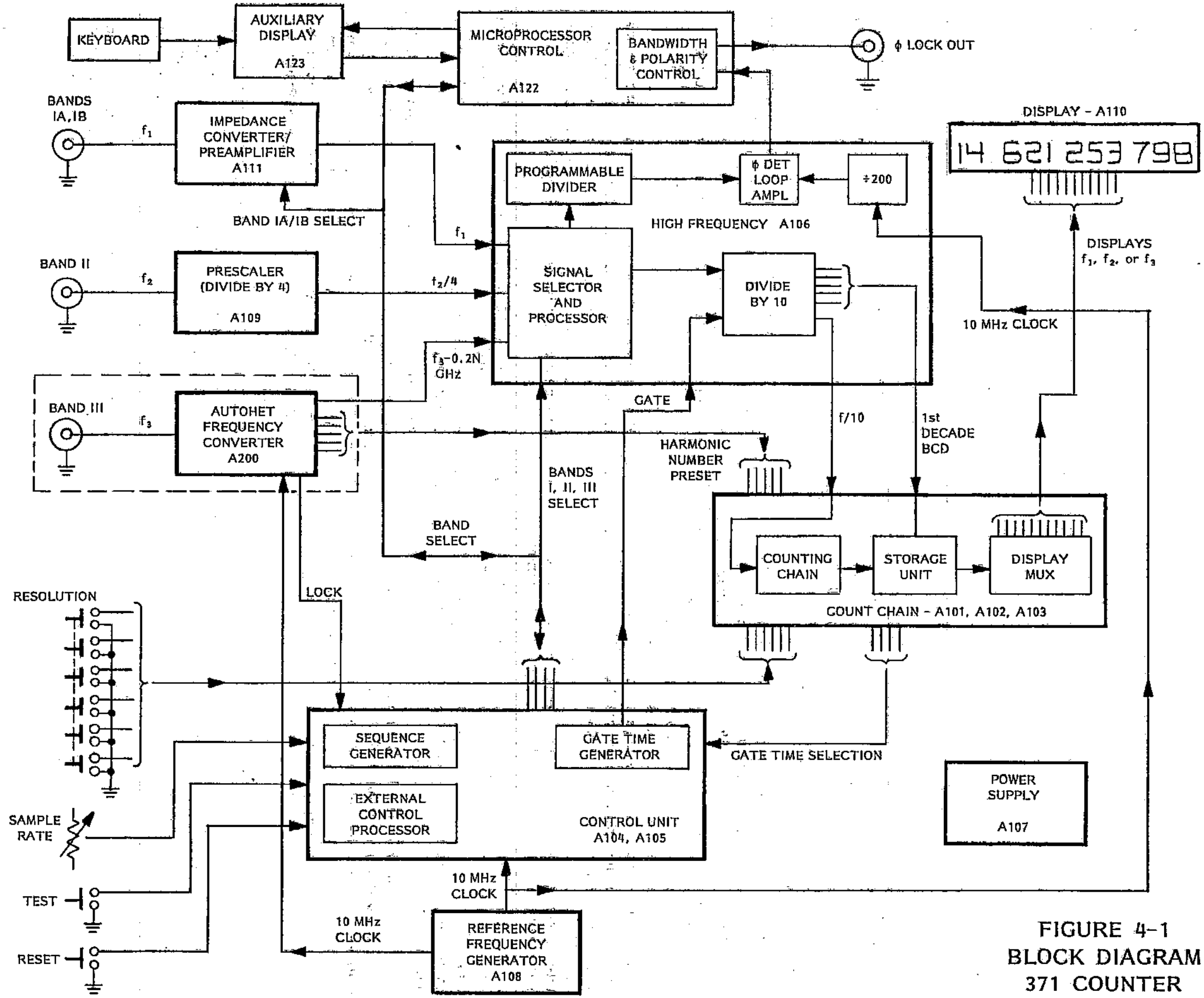

FIGURE 4-1
BLOCK DIAGRAM
371 COUNTER

-12, +5, -5.2 Vdc, and unregulated +18 Vdc. NOTE: This supply does not furnish the power for the oven stabilized Time Base Oscillators (Options 03, 04, or 05).

4-20. AUTOHET CONVERTER

4-21. The Autohet Converter is a self-contained assembly which performs the function of translating the microwave frequencies appearing at the Band III input, down into the range of the direct counter. This translation is accomplished by mixing the incoming signal with a known reference signal and then amplifying the difference frequency. The incoming frequency is then determined by counting the difference frequency and adding it to the known reference frequency. Refer to Figure 4-2, Converter Block Diagram.

4-22. The reference frequency is an integral multiple of 200 MHz which is derived from the 10 MHz Time Base Oscillator, thus maintaining the basic counter accuracy in the microwave band.

4-23. The Band III input signal passes through the PIN Diode Attenuator (A206) and is combined in the Mixer (A205) with the reference frequency from the YIG/Comb Generator.

4-24. The YIG/Comb Generator (A207) is an integrated assembly containing a Comb Generator and a YIG filter. The Comb Generator contains a step recovery diode to convert the 200 MHz sine wave input from the Source/-Amplifier (A201) into a train of narrow pulses containing all the harmonics of 200 MHz up to 18 GHz. This pulse train is then passed through a pair of YIG resonators which select the desired harmonic. The resonant frequency of the two stage filter is proportional to a magnetic field generated by passing current through a pair of coils within the structure. (A more comprehensive description of the operation of a YIG-tuned device is given later in this section.)

4-25. The Source Amplifier (A201) contains an LC oscillator operating at 200 MHz, which is phase-locked to the 10 MHz Time Base Oscillator (A116 or A112). This 200 MHz signal is amplified to produce up to one watt of output power to drive the Comb Generator section of A207.

4-26. The Mixer (A205) is an integrated microwave stripline assembly, containing a 3 dB hybrid coupler, a termination, a mixer diode, a matching network, a broadband DC return, and a bypass capacitor to separate the RF and IF signals. The Mixer produces two output signals: an IF signal with frequency equal to the difference of the reference and incoming signals, and a DC current resulting from rectification of the total power applied to the mixer diode.

4-27. Both the IF and DC signals from A205 enter Video Amplifier A204, where the IF signal is amplified, and the DC level used for control of PIN Diode Attenuator A206.

4-28. The circuitry required to control the Autohet Converter is located on two Converter Control Boards (A202 and A203). Their function is to set the YIG Filter within the YIG/Comb Generator (A207) to the correct harmonics of 200 MHz, and to provide both the IF frequency and the harmonic information to the Direct Counter.

4-29. To accomplish this, the YIG Filter passband is continuously tuned over the operating range until an appropriate signal is received from the Video Amplifier. The sweep is then stopped so the YIG Filter passband is centered on the desired harmonic. Converter Control 1 (A203) performs all the signal processing and provides digital commands to Converter Control 2 (A202) which contains the Digital to Analog Converters and the current driver necessary to tune the YIG Filter. A detailed operational sequence is described in Section 9 in the Converter Control 1 description (Figure 9-17).

4-30. LOCKBOX OPERATION

4-31. The source locking (lockbox) portion of the counter consists of three assemblies: the High Frequency board (A106), the Microprocessor board (A122), and the Auxiliary Display board (A123).

4-32. The High Frequency board selects the appropriate input signal, processes it, and divides it into two signals: one drives the gating and first stage of the frequency counting portion of the counter, while the other signal drives the phase locking portion.

4-33. The phase locking portion of the High Frequency board divides the selected signal down to 50 kHz in a programmable frequency divider. The 50 kHz signal is compared with a 50 kHz reference signal — derived from the 10 MHz time base clock — in a phase comparator, producing an error signal proportional to the phase (frequency) difference between the two signals. This error signal is sent to the Microprocessor board (A122) for amplification and processing, and then sent out to the signal source to correct for phase (frequency) errors.

4-34. The Microprocessor (A122) performs several tasks, including control of the Auxiliary Display board (A123). The Microprocessor interprets and processes the keyboard entries, and displays the appropriate data on the Auxiliary Display. It also controls the LOCK and PRESET indicators, and the BAND SELECT function (and indicators), in accordance with the appropriate keyboard entry commands.

4-35. In performing the YIG Preset function, the Microprocessor justifies the programmed frequency data to a multiple of 0.2 GHz, and then sends the data to the Converter Control 2 board (A202).

4-36. In performing the Lock command, the Microprocessor collects frequency information from the Converter and keyboard entries, and determines if a lock is possible. If so, it computes the IF frequency which should be present in the High Frequency board, and programs the frequency divider to generate the 50 kHz signal for the phase comparator. In Band II operation, it also justifies the frequency to be the proper multiple of 400 kHz (due to prescaler requirements).

4-37. Part of the lock operation is the selecting of loop gain (loop bandwidth) and polarity. The Microprocessor board perform this task by systematically programming gain and polarity information, and sampling the loop lock and bandwidth data. When the appropriate gain is reached, and both lock and bandwidth are correct, the processor returns to the keyboard/display scan. If a lock is not achieved, the processor returns to the keyboard/-display scan with the phase lock control voltage returned to zero volts.

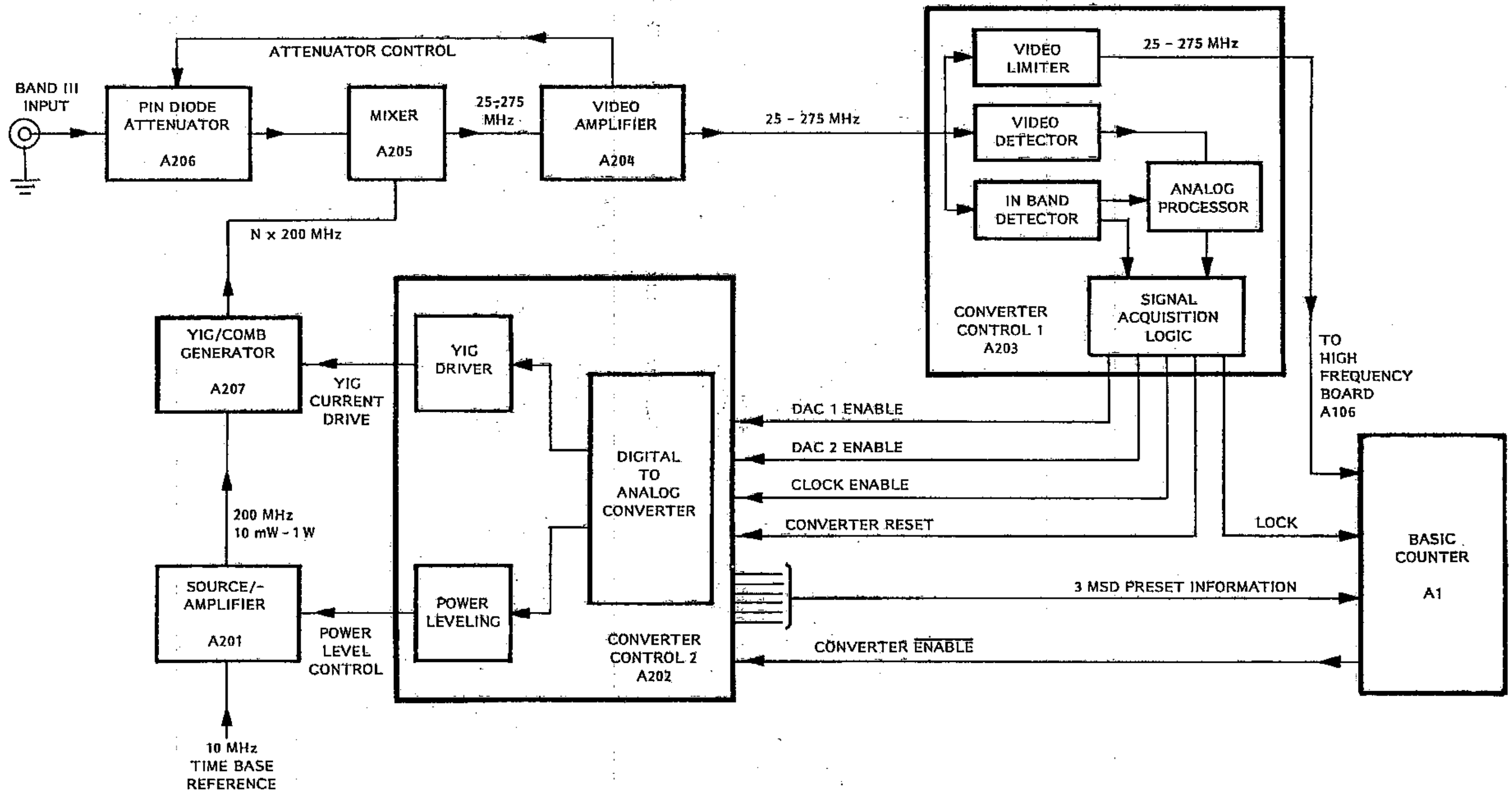

FIGURE 4-2
BLOCK DIAGRAM
AUTOHET CONVERTER

AN INTRODUCTION TO YIG FILTERS

Highly polished spheres of single crystal YIG (yttrium-iron-garnet), have a property called ferrimagnetic resonance. Basically, the ferrimagnetic resonance phenomenon can be explained in terms of spinning electrons creating a net magnetic moment in each molecule of a YIG crystal (see Figure A), Viewing the material macroscopically, there is no net effect because the magnetic dipoles associated with each molecule are randomly oriented (see Figure B). The application of an external magnetic biasing field, H_{DC}, causes the magnetic dipoles to be aligned in the direction of the biasing field (see Figure C).

An RF field can be used to create an orthogonal magnetic force. If the frequency of the RF field coincides with the natural precession frequency, there is a strong interaction called ferrimagnetic resonance (Figure D).

Figure E shows the basic elements of a YIG bandpass filter. The filter consists of a YIG sphere at the center of two loops. The two loops are perpendicular to each other and to the dc biasing field, H_{DC}. One loop carries the RF input and the other the RF output. When the RF signal frequency is the same as the natural precession frequency of the YIG, there is strong coupling between the input and output loops. Thus RF can only pass through the YIG filter at resonance. The resonant frequency is a linear function of the magnetic biasing field, H_{DC}. Generally, H_{DC} is provided by locating the YIG spheres between the poles of an electromagnet, and tuned by varying the current to the magnetic coils.

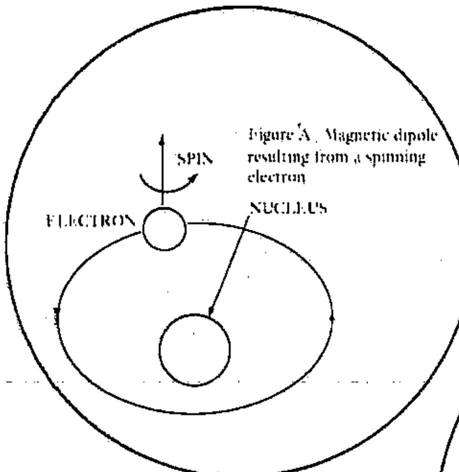

Figure A. Magnetic dipole resulting from a spinning electron

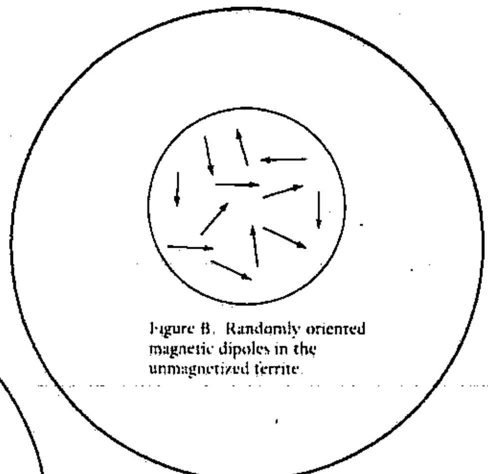
Figure B. Randomly oriented magnetic dipoles in the unmagnetized ferrite.

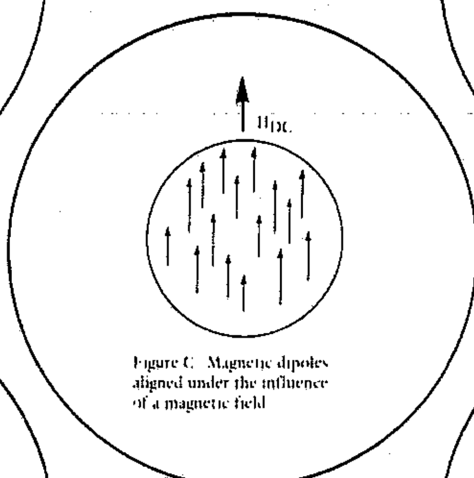

Figure C. Magnetic dipoles aligned under the influence of a magnetic field

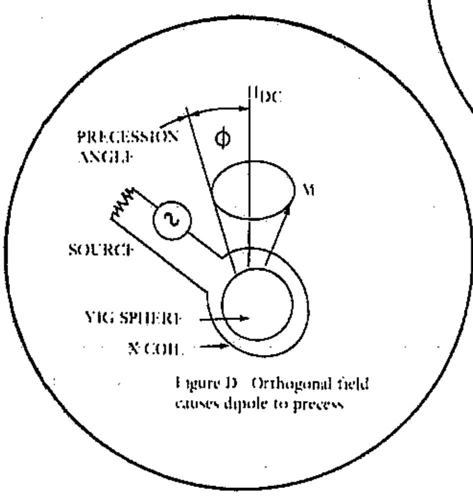

Figure D. Orthogonal field causes dipole to precess

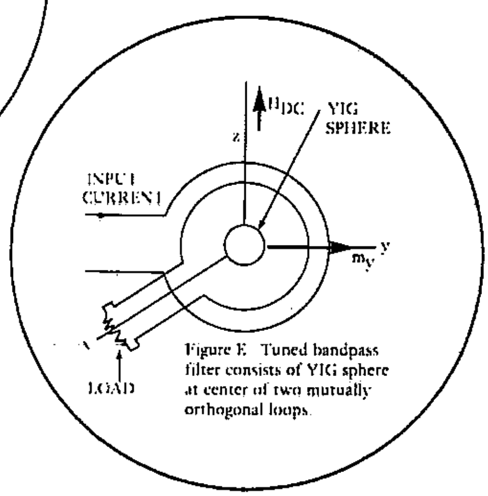

Figure E. Tuned bandpass filter consists of YIG sphere at center of two mutually orthogonal loops.