Microwave Isolators and Circulators: - Automatic Magnetic Calibration
Application notes and product details.
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This article describes how automatic magnetic calibration of microwave Isolators and Circulators can be achieved through the use of conventional Network Analysers and computer compatible magnetic equipment. The resulting systems have been shown to achieve a 20% higher production rate with significant improvements in the quality of product. Additional advantages are a significant reduction in the training time required by operators and operator skill requirements are significantly reduced. Meaningful SPC data can also be made available*.

Conventional manual magnetic calibration of Isolators and Circulators.

Conventionally, microwave isolators and circulators are connected to a Network Analyser, which measures the devices characteristics over a range frequencies. The permanent magnet in the device is then magnetically modified to adjust its microwave performance.

This magnetic modification is carried out with a piece of magnetic equipment which can be known by a range of names, including:-

“Magnet Treater”
“Magnet Demagnetiser”
“Magnet Setter”
“Magnet Calibrator”

These units are conventionally manually controlled equipment requiring a high degree of operator skill. The Microwave devices are initially magnetised to saturation and then “treated,” or “calibrated” to reduce the magnetic flux density levels of the permanent magnet, thereby modifying the devices microwave performance.

The Microwave performance of the isolator and circulator devices is normally a very exact requirement. This means that the magnetic calibration must also be very precise. It is in this area that Hirst can offer an automatic magnetic calibration process that will dramatically improve production rates, costs and quality.

Automatic magnetic calibration of Isolators and Circulators.

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Microwave isolator, circulator automatic magnetic calibration. (minimal system)
In automatic magnetic calibration of Isolators and Circulators, the manual “magnet treater” is replaced with a computer compatible, microprocessor controlled “Magnet Calibrator,” the MCSD unit.

This unit can communicate directly with the network analyser, but for purposes of software development and additional feature (see “dual system” later) the Network analyser communicates with a PC and the PC communicates with the “Magnet Calibrator.”

The calibration of the microwave isolator or circulator receives a series of demagnetising pulses of a magnitude which is increased in a controlled manner incorporating the Network Analyser as the feedback. This calibration is carried out automatically.

The result of this configuration is that microwave devices are calibrated at a faster rate (+20% complete calibration [magnetic and non magnetic calibration] rate under real production** and a much tighter magnetic calibration tolerance. This is achieved without operator intervention.

Dual Calibration systems.
As the overall calibration process of the Microwave isolator or circulator can also involve non magnetic calibration (i.e. using “tuning paste”) the single output MCSD unit will be idle for more than 50% of a full calibration cycle. A single, Dual output MCSD unit can be used to service two Network Analysers without delaying production. The effect of this will be to halve the number of “Magnet Calibrators” (or Treaters) in a production situation where multiple calibration stations exist. (one MCSD unit for every two analysers)

The maximum system shown above includes additional features in order to enable maximum efficiency of operators.

The MCSD unit and PC are mounted at a position between two Calibration stations that is between two Network analysers. In order for operators to initiate process operation, each operator has a local “Remote control unit.” The Remote control Unit enables the operators to initiate functions at their positions without the need to access the MCSD or computer unit directly.

In the configuration shown, the Calibration stations are also equipped with magnetising fixtures. This avoids the need for operators to leave their workstation to go to a central Magnetising station. Magnetisation can occur at the operator’s workstation, there by avoiding operator inefficiencies and the dependence on a single central magnetiser. (A single magnetiser failure does not stop all production.)

Each operator is also equipped with a “Calibration Coil” which is used to Magnetically Calibrate the Microwave Isolator or Circulator.

Operation.

The Operator 1, places the Microwave Circulator or Isolator into Magnetising fixture 1. The Operator then presses the “Magnetise” button on the Remote Control Unit. The MCSD unit then provides a Magnetisation pulse to Magnetising Fixture 1 and the microwave device is magnetised. Operator 1 the removes the Microwave device from the Magnetising fixture and connects it to Network analyser 1 and then presses the (magnetic) “Calibrate” button on the Remote Control Unit to start the Magnetic Calibration process.

The MCSD unit supplies a series of magnetic Calibration pulses to Calibration Coil 1. The levels of these pulses are controlled by software within the PC as a result of readings received from the Network Analyser. The Network Analyser readings are measurements specific to the manufacturing procedures to that specific device type. This procedure continues until a pass has been achieved or the device is failed.

When the Magnetic Calibration procedure is complete Operator 1 is then free to continue the device calibration with the non-magnetic calibration procedures. (This often involves the use of “Tuning Paste” or other mechanical adjustments.)

Depending upon the software options selected, the operation of the two calibration stations can be “interleaved” or one station can have priority over the other. The “interleaved” approach might offer the best solution to some situations, but depending upon the specific feedback rates from the Network Analysers etc. a priority approach may offer a better overall approach. It is possible in the “interleaved” approach to have multiple conflicts, each offering small delays, where as the Priority approach automatically synchronises the two stations to work in an alternating manner. The Conflicts then only occur at start up, and are otherwise largely “transparent.”

PC based software can be customer written or supplied as required.

The MCSD ranges of equipment are available in energies from 100Joules to energies in excess of 20 kiloJoules and are suitable for all types of magnet material. The descriptions above are largely based upon Ferrite magnet material and MCSD 100J systems (100 Joule.) Higher energy systems are available for Samarium Cobalt and other permanent magnet materials. The arrangements described are equally valid, but in all cases system arrangements and timings dependent upon the specific details of the individual microwave circulators and isolators concerned.

The following data is largely specific to MCSD100J models and options.

*SPC Data can be collected on the magnetic calibration process from initial, process and final magnetic and microwave performances. This will assist with quality and process control as well as component and build quality levels.

** The 20% production rate figure indicated is an improvement in the overall calibration process. That is magnetic and non-magnetic calibration combined. These figures are historical figures based upon improved production from an existing production facility that was upgraded from manual Magnet Treaters.
MCSD100J – microwave circulator and isolator – magnetic calibration

Features

- Automatic Calibration*
- Faster Manual Calibration
- Less operator training required
- Higher first time calibration rates
- RS232 remote control
- Statistical Process Control (SPC)

The MCSD 100J is a Magnet Charger, Setter, Demagnetiser also sometimes known as a Magnet Treater. The Capacitive Discharge unit is microprocessor controlled to give fast accurate and repeatable control of calibration pulses with a special modification to offer "in process" step size change.

Introduction

The ferrite permanent magnets in Microwave Ferrite circulators, isolators and similar devices are initially magnetised to saturation. The units are usually connected to a network analyser and their microwave performance monitored, as the magnets are progressively demagnetised to obtain the required Microwave performance.

This is normally a purely manual operation requiring skilled Operators to achieve consistent throughput at reasonable speed. The MCSD 100J offers automatic magnetic calibration* and faster manual calibration, requiring less skilled operation and offering other production advantages.

Additionally, due to the precision of operation of the demagnetising voltages, Statistical Process Control data can be available for the first time as a Magnet Quality feedback in the manufacturing process.

Automatic Mode.

By connecting a PC to the network analyser and using it to remotely control the MCSD unit, Microwave circulators and isolators can be automatically, magnetically calibrated utilising PC software developed specifically for the User's ferrite units. (The PC software can be developed by the User or Hirst Magnetic Instruments Ltd. (at an additional charge))

The Operator will connect the Ferrite unit to the Network analyser and initiate the process. The Network analyser, PC and MCSD unit will then proceed to rapidly calibrate the unit without Operator intervention other than loading uncalibrated units and unloading magnetically calibrated units.
(Mechanical adjustments to the cavity will still need to be carried out.)
The MCSD unit is remotely controlled with a simple ASCII command set, working examples and instructions are supplied together with RS232 lead.

**Manual Mode.**

In manual mode, (the simplest mode to implement), a minimum calibration voltage is entered into the MCSD for the Isolator or circulator type to be calibrated (say 200), together with a nominal step size. (Say 8)

These values will have been determined for the particular Ferrite from previous tests or production.

A maximum voltage may also be entered, in order to avoid unnecessary delays with faulty units.

The, previously magnetised, ferrite unit will then be connected to the Network analyser and its microwave performance measured on a continual basis.

The Operator will then press the pulse button, which will discharge an initial pulse of 200, followed increasing pulses of 8. (208,216 etc.)

As the microwave performance approaches the required levels the Operator will press have the choice of pressing the ½, ¼ or 1/8 step buttons giving finer and finer control without the adjustment via control knobs or keyboards.

This enables rapid processing in a controlled procedure without subjective setting and adjustments. This gives higher through rates. In turn has shown that "first time successful calibration rates can be higher leading to additionally higher through put rates. Finally, if the Operator does "over demagnetise" then noting the incorrect calibration voltage that was applied, in actual volts, the Operator can approach the correct calibration voltage much faster, having learnt about the individual unit. ***

As the MCSD offers an easier to use procedure, it enables Operators to successfully operate the equipment with less training than "control knob units".

As the MCSD unit calibrates using real calibration voltages, data can be collected via the RS232 serial interface as to actual calibration voltages. This data can be used to monitor production quality of the ferrite units, in particular magnets

**Magnetising.**

Depending upon the particular design of the Ferrite units to be calibrated, Magnetisation can be carried out with a special magnetising fixture or with the Setting coil. Additional energy might be necessary but MCSD units are also available in higher energies.

Hirst Magnetic Instruments Ltd. prefer to supply Setting or Calibrating coils without soft iron cores. Although such coils can provide higher fields, they affect the ferrite magnetic circuit. Once the ferrite unit is removed from the soft iron the microwave performance will change.

This does not occur with Air-Cored coils.

**Magnetising Fixtures and Demagnetising (Setting, Calibrating) coils.**

A wide range of standard coils and fixtures are available from Hirst Magnetic Instruments Ltd. Special coils and fixtures can also be designed. A Calibrating coil designed specifically for a User Ferrite unit can have significant advantages in magnetic performance and ease of use.

**Economics.**

A User investing in a calibration station will invest significantly more on the Network analyser than the Magnetic calibration equipment. For the best return on that investment the production rates of the calibration station should not be limited by slow, low cost, magnetic calibrators (or Treaters). The MCSD100J has a proven record in fast operation and reliability.

**OPTIONS**

A Additional ½,1/4 and 1/8 step pulse buttons (as discussed in Manual mode above).
B Two Output Version (Magnetising and Calibration outputs)
C 19-inch rack mounted version.
D 115Volt AC 60Hz Version
E Remote front Panel.
F Seven segment LED display (for faster operation).

Fully Specifications for the various MCSD units can be found on the Hirst Magnetic Instruments Ltd. website.

*** Performance will depend upon the specific design of User Microwave ferrite circulators and Isolators.

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