BROADBAND ORTHOGONAL ARRAY ANTENNA SYSTEM
MICROPROCESSOR CONTROL AND COMPUTATION

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Abstract
A broadband orthogonal array antenna system and associated control circuitry have been designed to reduce the man hours required when making spectrum occupancy studies. Effective omnidirectional coverage is obtained by rapidly switching among arrays of conventional antennas; resultant field strengths are calculated and recorded using a microprocessor. The system is man pack portable, covers from 10 kHz to 18 GHz and is capable of recording fields up to 100 V/meter. The system has demonstrated a factor of 50 to 1 reduction in man hours required to carefully measure and record spectrum occupancy over conventional non-automated searching. This paper concentrates on the microprocessor computation, control, display, print out and convenience features.

INTRODUCTION
This paper describes a set of equipment, with emphasis on the automation and control portion of the equipment, developed to aid in the making of electromagnetic interference (EMI) measurements in the frequency range from 10 kHz to 18 GHz. The objective of this equipment is to speed up and simplify a conventional type of EMI spectrum occupancy measurement procedure using a set of standard field intensity meters (FIMs); this goal has been met and demonstrated with a test that showed a 50 to 1 reduction in required man hours to perform a given task.

The equipment is intended for use with a specific line of commercially available receivers. The system assists the operator by scanning rapidly among elements of an orthogonal array antenna, computing total scalar field received, printing the data acquired, and providing a number of convenience features.

The system controller uses a CMOS microprocessor, contains a thermal "grocery tape" printer, is rated from 0° to 50°C, is portable, consumes 17 watts (30 watts when printing), and weighs 14 Kg (30 lbs.). A number of convenience features such as visibility of display in direct sunlight, threshold level set for discrimination against numerous small signals, display dimming, filtered convenience outlet, and limited operator error and recovery information, are provided.

BACKGROUND
The performance of a carefui search for signals as a function of frequency and direction of arrival using a field intensity meter (FIM), traditionally involves one man tuning the FIM and observing received signals, a second man rotating a dipole antenna to ensure maximum received signal, and a third man recording data. The data usually consists of frequency, measured signal voltage, and optionally the time of day. Later the signal voltage must be converted to field strength using antenna versus frequency correction factors and cable losses. This procedure is expensive in terms of the number of personnel required (3), and the time (generally measured in hours) required to manually scan, record, and correct signal readings. It was toward the goal of reducing this expense that the present system was developed. The design goals were to allow complete spectrum occupancy studies to be completed in minutes instead of hours, by one man instead of three, using portable equipment.

Figure 1 gives a block diagram of a typical complete system configuration needed to cover the frequency range from 10 KHz to 18 GHz. If a smaller portion of that frequency range (say 30 MHz to 1000 MHz) were to be covered, only a portion (the center one-third) of the total system need be fielded.

This paper will concentrate on the box labeled "main controller" and its characteristics and capabilities. A companion paper by Gerome Reeve will discuss the antenna systems and rf switching (at the top of the block diagram).

CONTROLLER
The controller receives frequency and amplitude information from one of three receivers via cables labeled "log video", "penlift", and "programmer", (refer to Figure 1). The controller directs the switching and selection of individual orthogonal antenna elements via the cables labeled "control". The controller does not control the receiver. Depending on which of six modes the operator has selected, the controller processes the data and prints the results.

The capabilities of the controller are listed in outline form below:

1. Switch (among multiple antenna elements, and indicate which element is selected).
   a. Rapid scan of all elements sequentially to cover all directions of arrival. To be used while automatically or manually tuning the receiver.
   b. Periodically sample all elements and then select the element having the strongest signal. To be used for maximum intelligibility and to aid in direction of arrival and polarization determination.

2. Computation
   a. Supply correction factors for antenna gain and cable attenuation as a function of frequency.
   b. Compute total scalar sum from three measured orthogonal inputs. Display the true field strength.
   c. Find signal peaks.

3. Logging Aid
   a. Print all variables, such as frequency, signal strength, receiver detector selected, antenna elements chosen, and time of day, for each signal encountered or by operator request.
   b. Provide a real time clock.

4. Automatic Operation
   a. Record signals encountered versus frequency (when the receiver is put on spectrum scan).
   b. Unattended operation. Will monitor a given frequency and record occupancy data.
FIGURE 1. BLOCK DIAGRAM OF TYPICAL SYSTEM CONFIGURATIONS
SOFTWARE AND MICROPROCESSOR DESIGN

The CMOS Microprocessor chosen proved adequate for the task. It follows an architecture which is now almost 20 years old. This design uses a 12 bit bus, which gave us sufficient precision without resorting to double precision arithmetic. The microprocessor was run on a 2.048 MHz crystal, which was also hardwired divided by 2^n (2048) to provide 1 ms clock pulses for timing and the real time clock. Microprocessor speed was adequate for the fastest antenna switching times required (about 3 ms) and for the other mathematical and control functions.

The memory consists of 3 1/2 K (1K = 1024) words of CMOS EPROM and 1/4 K of CMOS RAM. A portion (1 K) of the EPROM contains the antenna factors and receiver constants that configure the controller for any of the 3 receiver-antenna combinations. This 1 K of memory is called a "personality module" and plugs into the back panel of the controller. A given plug-in memory contains all constants needed to cover one of three bands (1) 10 kHz to 32 MHz, (2) 30 MHz to 1000 MHz, or (3) 1 GHz to 18 GHz. By using one controller and three memories, the entire range can sequentially be covered.

Because of the limited main memory size (2 1/2 K) the square root of the sum of the square's operation (used to get the total signal strength from three orthogonal antennas) was accomplished using a look up table. The table contains 20 pre-computed amplitude values of the square root of the sum of the squares of two vectors at right angles. The resultant amplitude of three orthogonal values is computed for two signal vectors at a time, using the above routine. A simple interpolation routine allows precision of one-tenth of a dB to be carried in the machine, just under 5 dB.

The above "antenna pattern" correction is in addition to the "antenna factor" correction supplied by the microprocessor. This "antenna factor" or system response versus frequency correction is obtained by simply immersing the antenna in a known standard field (usually 1 Volt/meter), and then providing for the addition (or subtraction) of a number of dB so the display reads the correct field strength (usually 120 dB V/m). This was done for each element of each antenna, across the frequency range of the receiver, to build up the table of values stored in each personality plug-in memory. Note that the display resolution is in dB, so that as frequency is changed, the correction changes in steps of one dB (11.2% voltage change).

The microprocessor has eight ports implemented as follows: two input and two output ports to the front panel controls and displays, an input from the receiver, an output to the printer, an input from the A/D converter, and finally an output port to control the A/D converter, the analog multiplexer, and the antenna element switching. Modified commercially available back plane, CPU, and port driver cards were used. Custom memory, A/D converter, and interface cards designed for the system.

CONTROLLER OPERATION

The system operator initially chooses which detector is being used, Field Intensity (FI) for average, Peak for maximum signals, or Log Video for rapid response. One of several controller modes may then be chosen; generally, whether the antenna elements are selected automatically by the controller, or manually by the operator.

Automatic antenna selection is intended to aid the operator while tuning the receiver and hunting for signals. Rapid Scan mode simply connects each element briefly (typically 10 ms) in sequence to the receiver. This insures no direction of arrival is missed while frequency is changed. A second automatic mode is Follow Max Element, in which the microprocessor rapidly scans all elements (typically 3 ms each) and then spends 90 ms on the strongest one. This aids somewhat in direction of arrival and polarization determination, and in increasing intelligibility of modulation.

Manual antenna selection can be controlled by the operator for slower, more detailed determination of individual element response.

The Total mode can be used with either automatic or manual antenna element selection. This mode takes the square root of the sums of the squares of the three (3 highest in the case of the 6 element spiral antenna) signals provided by the 3 elements, giving the magnitude of the total field strength present.

The Print command will record field strength, frequency and other system parameters including time of day on a 20 column thermal printer.

Finally, the Max Finder mode will automatically record signal peaks, above a preset threshold, either while the receiver is scanning a particular band, or while unattended and monitoring a single frequency.

Other controller capabilities include printing the contents of the personality plug-in memory, disabling the "antenna factor" corrections for calibration runs or use with other antennas, thumbwheel entry of constants for extra cable length or attenuators, some operator assistance in case insufficient data is entered for a Total, and clock setting.

SUMMARY

A portable, automated EMI measurement system using commercially available field intensity meters has been designed, built and tested. This system allows accurate surveying of EM signals through the use of microprocessor based antenna element switching, data computation, display of true field strength in dB V/m, and data logging. A test of performance of a specific measurement task has demonstrated a 50 to 1 reduction in required man hours.