Raven Research Limited

Application of the RR1003 for HF Distribution Systems for Surveillance and Frequency management

Technical Discussion

11th February 2004

Raven Research Limited
Westminster House
Bath Road
Padworth
Berkshire
England, RG7 5HR
Telephone 44-(0)-118-9714540
Fax: 44-(0)-118-9714120
E-mail: info@raven-research.com

Contents

1. Introduction

Raven Research regularly receives requests for quotation for HF band RF distribution and matrix switching systems. The details of the technical requirements vary but are usually a selection of common requirements, contained in most service specifications.

Raven Research has a ‘standard product line’ of signal exchange units, which can be configured into switching systems to meet these requirements, precisely. The following paragraphs will show by example how this is done.

2. Appreciation of Requirements.

2.1. RF Configuration

The following three types of matrix system describe a typical requirement:

a) Matrix 1 - 30 inputs x 60 outputs
b) Matrix 2 - 16 inputs x 60 outputs
c) Matrix 3 - 16 inputs x 30 outputs

Connectivity is to be non-blocking. The systems are to be configured so that expansion of the number of outputs is possible by purchasing extra units, and still maintaining a non-blocking configuration.

The parameters of these systems are usually summarised as follows:

Frequency Range		: 1.5MHz to 32 MHz
Noise Figure		: <10dB
Output Intercept Point 3rd Order		: >29dBm
Output Intercept Point 2nd Order		: >60dBm
RF Gain		: 0dB +/-1dB
Isolation:	Input/Input	: 50dB
	Input/Output (On/Off)	: 60dB
	Output/Input	: 40dB
	Output/Output	: 40dB
Switching Speed		: <250us*
VSWR		: 1.5:1
Input Power (1dB compression)		: +17dBm
Maximum RF input Level		: >2VRMS (+19dBm)

*This specification is often quoted as ‘desirable’.

2.2. Control and Power Supply

Power Supply	: Single phase 240Vac 50Hz
BITE	: To be included.
Local Control	: Local control is to be carried out by local control terminal. Local control function <u>not</u> required on front panel.

Remote Control		: All matrix switch controls to be able to be carried out via a remote control port using a physical Ethernet connection and TCP /IP socket connection.
Remote Monitoring		: Critical parameters of the switch and controller are to be able to be monitored via Ethernet port or via a separate port.
Power Up Configuration		: Power up to last configuration or customer prescribed preferred configuration.

2.3. Physical

RF Connectors	- Input	: BNC
	- Output	: BNC
Operating Temperature		: 0-50degrees C
Relative Humidity		: 0-95% non-condensing
Mounting		: 19” Rack Mounting System
Access		: Unit to be fitted with slide rack mounts allowing the unit to be extended for maintenance without removal from the rack.
Cable Access		: All cabling to terminate at the rear of the chassis and be rear accessible.
Power Connector		: IEC 3 pronged recessed receptacle.
Wiring		: In accordance with local legal standards
Earthing		: The unit chassis to incorporate a convenient and substantial earth connection point for attachment to rack /building earth.

3. Proposed Solutions

To satisfy the requirement detailed above, Raven Research will propose three configurations of equipment, the simplest configuration being matrix 3 - a single standard RR1003 Signal Exchange Unit. As each of the matrix types is to be built up using this unit as a standard building block, the RR1003 will be described first and the larger configurations covered in order of size.

3.1. Matrix 3 - (16 inputs x 30 outputs)

Raven Research has a signal exchange unit which has been specifically designed as 16 input x 32 output switching matrix, alternatively referred to as a Signal Exchange Unit. The standard commercial data sheet for this unit is given elsewhere on this site. A block diagram of the RR1003 is given in Figure 1.

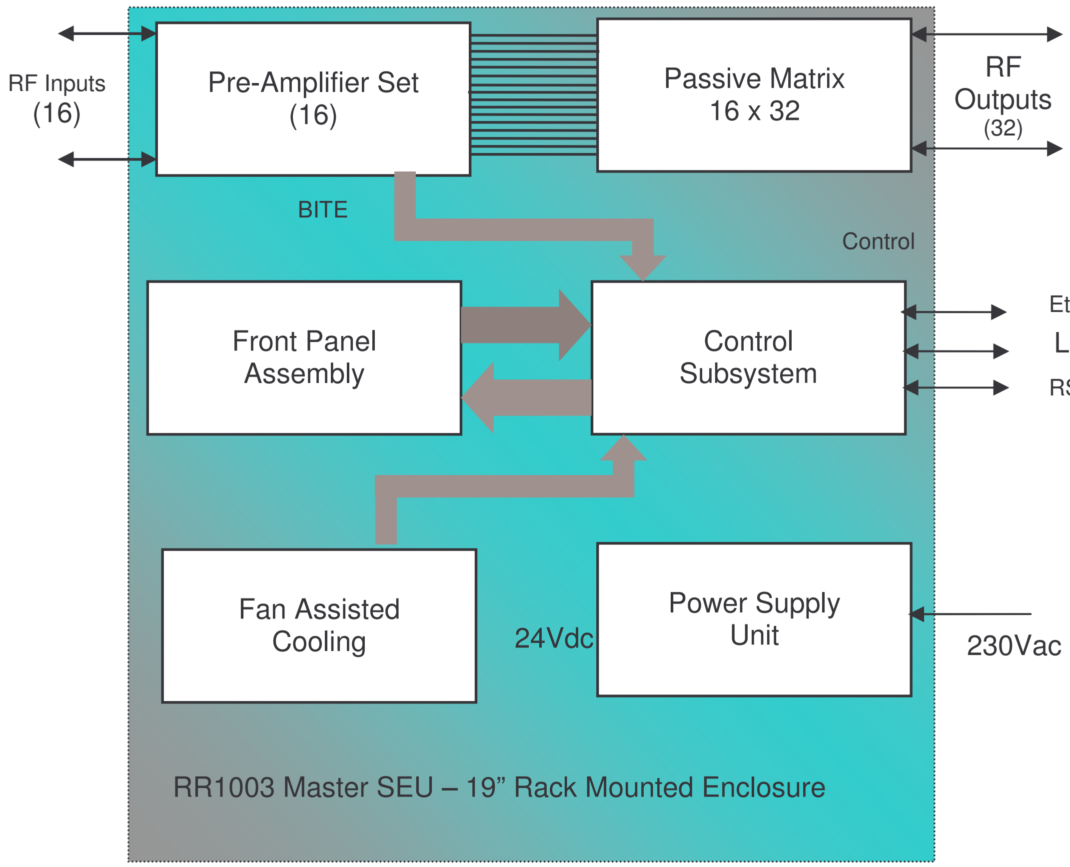

Figure 1 - Block Diagram of RR1003 Signal Exchange Unit

The RR1003 is a complete, self-contained matrix subsystem in its own right. The RF path includes a low noise HF pre-amplifier with high linearity, followed by a passive matrix system and equalisation circuits. The passive matrix scheme is implemented in such a way as to produce a switching connectivity that is non-blocking in the forward direction. That is any number or all of the output ports can be connected to any one of the inputs, without affecting other switched paths.

3.1.1.RF Pre-Amplifier

The amplifiers included in the current production system are designed using feed-forward techniques to cancel noise and inter-modulation products. As a result the amplifier features a noise figure below 5dB, while maintaining an output 3rd order intercept point of +65dBm and 2nd order intercept point of +120dBm. This is achieved while still running all active devices well below their rated power levels, with the complete amplifier drawing about 550mA at 24Vdc. The amplifier assembly includes front end protection, comprising spark gap and diode chain, as well as a relay which is used to isolate the RF input while the unit is off, or if the input power exceeds the rated level for long periods.

3.1.2.Switching Technology

3.1.2.1. Relays

The advantage of using relay devices is the very high isolation and negligible intermodulation distortion produced by relay switches. The main disadvantage is that relays do wear out after considerable time in service. They must therefore be treated as a ‘lifed item’ from a service and support standpoint. It must also be allowed that relay devices are slow, adding 5ms to the system switching time.

The standard switching matrix uses sub-miniature relays as the basic switching element. These are bifurcated, metal contact devices, produced principally for the cellular radio market. These remarkable devices maintain insertion loss below 1dB up to 1000MHz (negligible at HF) and are rated to switch up to 10 watts at 900MHz. Under these conditions, the manufacturer guarantees the relay for 300,000 operations. However, in this application, the relays are rarely subject to power levels in excess of 0dBm.

Sample life tests have been continuously carried out at Raven Research since 1995, on a number of relays under the most strenuous conditions ever likely to be encountered in a HF receive matrix. The units under test have never actually been tested completely to the failure point. However, we have reached 65 million operations, hot switching at +33dBm in the HF band. After this, the insertion loss had not degraded significantly. Nevertheless, on average, we recommend that switch cards of this type are replaced once the relays have complete thirty five million operations.

It has been noticed also that relays that are not switched for very long periods of time may have a tendency to stick. To overcome this, we recommend that the relays are exercised as part of a routine maintenance procedure, if they are located in an RF path that remains undisturbed for more than 12 months.

Raven Research is able to offer a service logging facility (software program) which logs the number of switch operations for each relay, and advises the service engineer when a replacement switch card is advisable or that exercising is required. This can be done via the Ethernet interface.

3.1.2.2. Solid State FET Switches

Hitherto, solid state devices have not been used in HF switching for sensitive receiving systems. The primary reason for this was that the (PIN) devices need too much current to achieve acceptable levels of linearity in a broadband HF front-end system. They also exhibit a significant insertion loss at HF.

In a recent development, a low current solid state device (FET switch) has become available which does exhibit sufficient linearity to make it useful in a HF receive system. Though (of course) it is not as good as a relay in this respect, they have reached a performance level akin to the best of the pre-amplifiers and therefore make no significant contribution to intermodulation distortion in the system. They can, at last, be used in this application.

These solid state devices bring the advantage of increased switching speed. The SS switch can operate in a few microseconds, making the control subsystem the defining item in system switching time.

An option now exists to incorporate such devices into the switching cards to remove the inconvenience of ‘lifed items’ in the system. They exhibit a second order IP point of +90dBm and third order of +50dBm, which will set the overall performance level of the switching matrix.

3.1.2.3. MEM Devices

A new development is the advent of MEM devices. These are a new technology, which in a switch exhibits the electrical performance of a relay but the mechanical function of a solid state device. These hold out the promise of a much improved lifetime (10,000,000,000 operations) and, even more exciting, the prospect of a passive latching device, thereby removing the necessity to power the switch in ‘ON’ state. These devices are currently 30 times more expensive than the equivalent relay/SS devices but we expect prices to reduce as the technology matures.

3.1.3.Design Performance

The configuration of Figure 1produces a matrix with low noise figure (5dB) and very high Intercept Points (45dBm and 90dBm for 3rd Order and 2nd Order respectively).

RF gain can be set within limits from 0-4dB. In practice it is advisable to maintain a small gain to overcome system noise figure specifications, so the stand alone RR1003 should be set to 0.5dB+/-0.5dB.

The design produces high reverse isolation, inherent in the design of the amplifier. However, the design can only achieve an output to output isolation of 35dB minimum at some points in the band (40dB + over most of the band). This can be supplemented (at extra cost) with active isolators, placed on the matrix outputs to add an extra 15dB of isolation, thereby achieving the desired high isolation in some applications. The RR1846 is a 19” rack mounted series of isolators (16 per rack).

3.1.4.Control Subsystem

The master unit we offer for this application contains its own Ethernet interface and a front panel control facility. In fact the control subsystem is based on the PC104 processor and this is a very powerful and flexible facility. In effect, it is a built-in 486 level computer with compact flash memory facility. The system can therefore accommodate almost any customer defined control facility. In this instance, we offer the Ethernet option configuration as the master signal exchange unit. Our offer includes a front panel facility, comprising a keyboard and 2 line 40 digit LCD display. However, both local (not front panel) and remote control facilities can be provided using commercial PCs as the terminals if this is preferred. Raven Research can provide control programs to order, as required.

As described later, the larger systems will be built using this unit as a master and a different option as a slave. The slave units are usually connected to the master via a proprietary data bus based on RS232 or RS485 electrical standards. A parallel bus, such as IEEE488 might also be used.

However, where fast switching is essential, Raven Research offers a special parallel bus, designed for high speed data transfer to allow several switch commands to be transferred in a single datagram. This is necessary to achieve the speed of switching needed in some systems.

3.1.5.Physical Characteristics

The whole system is contained in a single 19” rack mounting unit, 4U high and 600mm deep. All electrical connections are made to the rear panel.

The unit is mounted on extendable slide rails and access for maintenance is through the removable top cover.

The equipment consumes 175 watts when operated from DC power. This rises to 350W when using the 240Vac prime power option. Cooling is by ‘fan assisted’ air, drawn in through the front panel and expelled at the rear panel.

3.1.6.Prime Power

There are several options available for prime power. In this instance we offer 240Vac but 24Vdc is also available for use with multiple redundant power supplies, if necessary. The 240Vac prime power connector is usually a ‘3 pin IEC plug (recessed)’. Section 6 is a more comprehensive discussion of power issues in larger matrix systems

3.1.7.BITE

The unit is covered by an extensive BITE system.

The fans are monitored in such a way as to raise an alarm if the fan stops turning.

The amplifiers are monitored for supply current. The amplifier supply current is considered a very good indication of the good working order of the amplifier. In fact, supply current is the best measure that can be taken, short of a real RF measurement. Should the supply current to an amplifier drift outside a pre-set limit, then a relay is operated, a local indicator is activated and the alarm is raised both on the front panel (if fitted) and remotely, through the control subsystem.

The switch matrix is monitored for the presence of the correct dc coil operating voltage. The presence of short or open circuits would lead to relays not operating, even though the control system indicated good operation. This feature guards against this possibility.

The unit’s internal control system monitors the BITE facility and can be programmed to send a remote indication to report a fault automatically, whenever it receives a command. Alternatively, it can be made to wait until interrogated by a remote controller, to determine the status of the unit. Under further remote interrogation, the unit will report the type of fault.
The above remarks are extended to include the slave units, when the system is expanded, as will be described below.

3.1.8.Switching Time

In a typical RF relay circuit, the relay switching time is typically less than 4ms. This time is the delay for the relay armature to operate but the time to switch an individual element must also include the command processing time. In a large and complex system, where the serial bus is the principal data link, this will typically add up to 5ms to the relay operating time.

However, the control circuit and the algorithm for switching in the RR1003 are different. In the RR1003, the switching routine involves addressing every cross-point, every time for every switching operation. This means that the time to switch one single cross-point is slightly higher than could be achieved with circuitry that addresses only one single cross-point (about 1ms longer). The advantage of the system is that multiple switching commands are handled in almost the same time. Thus the time to switch one cross-point is 8 ms, but the time to switch a larger number of cross-points simultaneously, say, 10 (or 64 for the bigger system) is only 10ms. This has proved advantageous for many operations we have encountered.

3.2. Matrix 2 – (16 inputs x 60 outputs)

The simplified RF block diagram of Matrix 2 (16 inputs x 60 outputs) is given in Figure 2. The system will comprise a set of 16 pieces RR221H passive input splitters, dividing each signal into 2 paths.

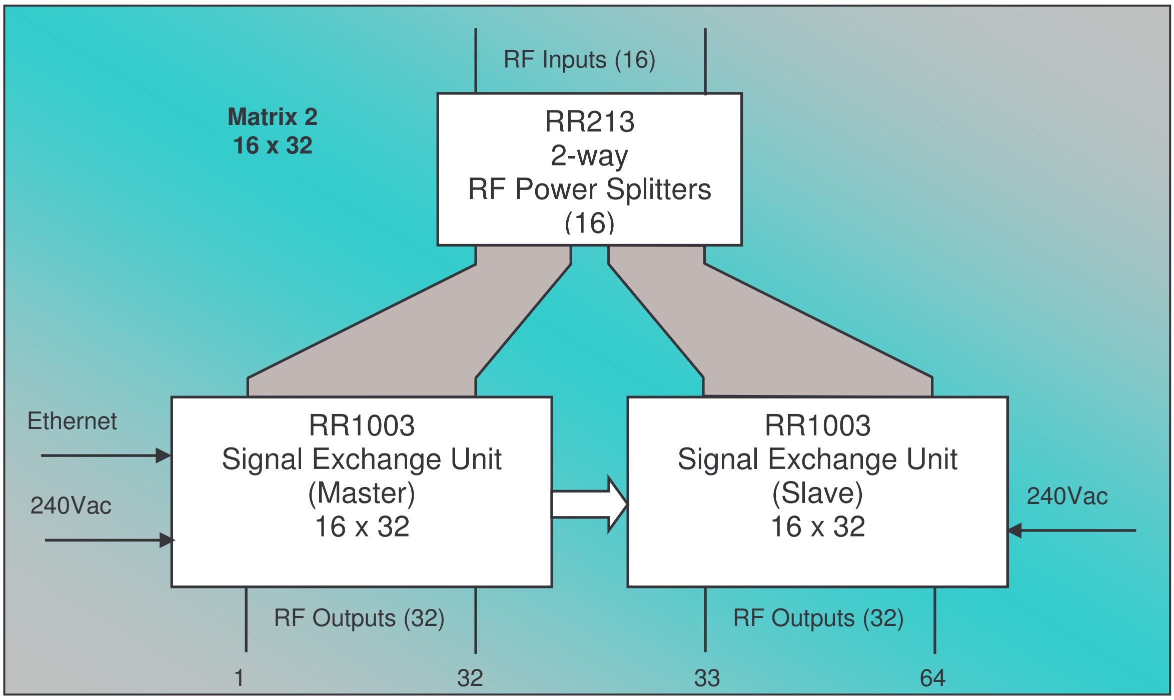

Figure 2 – RF Block Diagram 16 input x 64 Output Matrix

Each of these signals is taken to the input of an RR1003 SEU, which provides the 16 x 32 switching matrix function as described above. Thus sixty-four outputs are provided each with non-blocking access to the 16 inputs.

The inputs signals are divided by passive power splitters, which exhibit a through loss, including splitting loss and attenuation, of 3.5dB. This loss of signal is made up by an increase in gain within the SEU of 3.5dB, so that the overall RF gain of the system remains in specification of 0+/-1dB. The increase in gain is achieved by providing a modified version of the pre-amplifier, with the gain set to 21.5dB instead of 18.0dB, as on the standard unit.
In placing loss in the very front end of the system, the noise figure of the system is increased by the same amount as the attenuation. However, as the RR1003 has such a low noise figure, it is possible to place this attenuation in the system and still meet the standard target system noise figure of 10dB maximum, and by a good margin.

The alternative is to provide an active multicoupler in the front end, which compensates for the first stage divider loss and attenuation. However, if the signal division is only two-way, this is an unnecessary expense, with no performance advantage.

Two RR1003 signal exchange units (SEU) are provided for this system, one a master and the other a slave. Remote and local control of the system is achieved through the master RR1003, which acts as the interface to the Ethernet LAN.

The processor in the master SEU accepts system commands from the remote controller or its own front panel and processes these commands to determine which cross-points must be operated ('on' or 'off'). Where cross-points located in the slave SEU are to be activated, a command is sent over the local control bus.

It should be noted that the front panel control on the master SEU is a standard feature, intended as a 'fall-back' and maintenance facility. However, it may be necessary to have a local control situated away from the exchange units or featuring facilities not included in the standard master SEU. In this case, two PC terminals can be provided, one operating as a local control and the other (peer of the first) acting as a remote control facility.

3.3. Matrix 1 – (30 inputs x 60 outputs)

The simplified RF block diagram of Matrix Type 3 (30 inputs x 60 outputs) is given in Figure 3. The system comprises two matrices of Type 2, connected together with RR1401A RF switching units.

A set of two RR1401A units, each comprising 32 x SP2T RF switches, is used to connect each output to either one of the sub-matrix systems. Thus sixty-four outputs are provided each with non-blocking access to 32 inputs. The switches used are relay devices, the same as those used in the signal exchange units, and they have no significant effect on the RF performance of the system.

The system is again controlled through one master SEU, with the other three SEUs and the switching units configured as slaves. (See Figure 4) In this instance, the Raven proprietary parallel bus is used and interconnection of the data bus is done through a distribution box. This is a passive wiring interconnection but is necessary because the Raven Research data bus requires that each unit in the system has a single unique unit selection wire, which must be routed accordingly.

Once again the comments on the location of local and remote control facilities made for Type 2 matrix are valid. The switching time for switch commands approximates to 10ms, regardless of the actual number of switches operated. The control and power distribution for this system control option is illustrated in Figure 4

4. Software Design

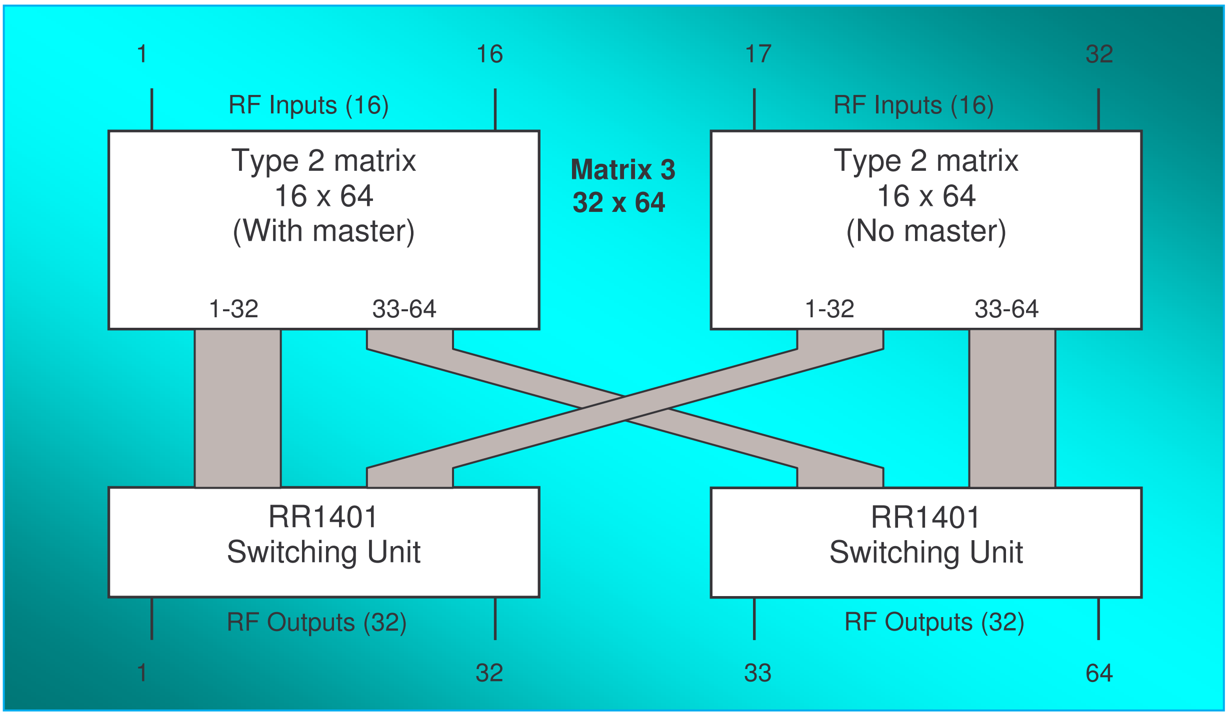

Figure 3 – RF Block Diagram 32 Input x 64 Output Matrix

Bespoke software, resident in the flash memory card in the master, is responsible for processing remote commands and issuing local commands to signal exchange and switching units. Revertive data is processed throughout the system's internal data bus to confirm satisfactory operation and 'system status' information can be returned to the remote controller, if required.

When not responding to remote commands or polling, the software ensures that all RF units are refreshed, using current settings that are stored within the master SEU memory. The status of all RF units is continuously monitored to insure instant recognition of any fault condition.

All critical data is stored within non-volatile (flash) memory so that, in the event of a mains power failure or critical disruption of internal communications, the entire switching system will be automatically re-initialised when normal operation is resumed.

The current settings of the system are stored and continuously updated as commands are sent to the system. Thus, the system will power up to the last known configuration on 'switch on' (if this is the option selected).

The external communication protocol can be user defined. For instance, the customer might have requested SNMP. If this were so, the instruction set using this protocol would be confirmed with the customer at the outset of the manufacturing program.

If the requirement was for a local control terminal, not located on the front panel, the systems would be acceptance tested using two PC's as 'local' and 'remote' controllers.

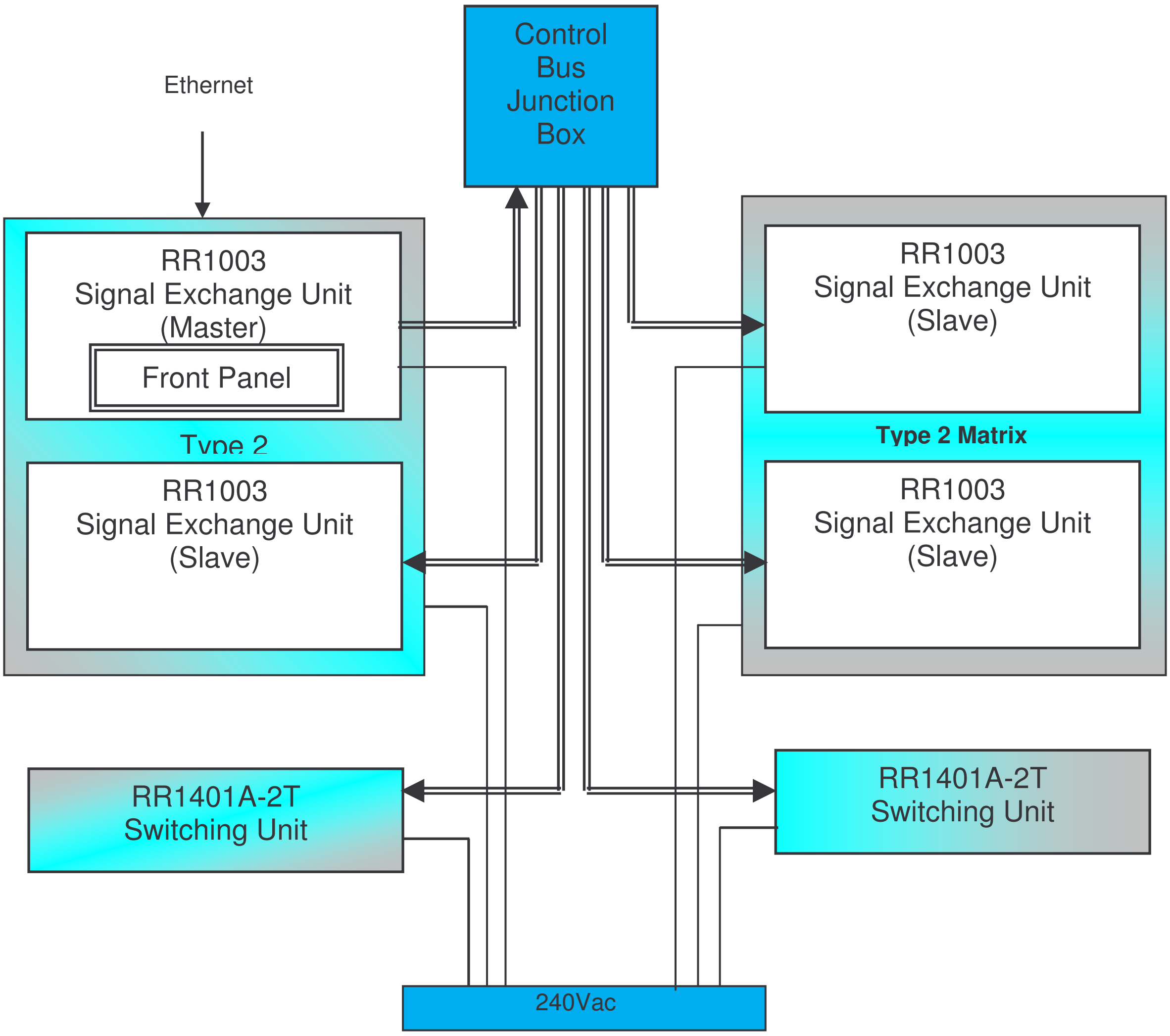

Figure 4 – Control and Power Block Diagram for 32 x 64 Matrix

5. Special Functions

A number of special functions have been developed for the SEU product and will be provided as standard, or deleted if incompatible with the customer's control program. They have been developed to allow the operator, working locally or remotely, to establish the status of the system and make changes as efficiently as possible, using single instructions. The following functions are available, unless it is requested that they be omitted.

5.1. Local Over-ride

This function is provided to allow the local control to be de-selected remotely. This ensures that if the SEU is inadvertently left in local mode (possibly after maintenance activity), it can be overridden remotely. This also provides the facility to override the local control, in case of an operational emergency.

5.2. Interrogation Function

This function allows the RF configuration status of the system to be established, by the use of a single remote instruction. A similar function is available locally, using the front panel keypad.

5.3. System Clear Function

This enables the system to be cleared of all system connections with a single remote instruction. This is used whenever a fresh start situation arises.

5.4. Receiver Block Allocation

This function enables a block of outputs (receivers) to be connected to a defined input (antenna) by a sequence of front panel key strokes. This is particularly useful during installation and maintenance.

5.5. Relay Lifetime Software Monitoring Facility

The proposed hardware provides an optimum approach to providing a high performance off-the-shelf (COTS) solution that closely matches the general requirement of the industry. However, there is one area, which may yet be of concern; that is the lifetime of the relay switch. The relay solution in the RR1003 SEU provides the most superior performance possible in terms of loss, isolation and linearity, where switching speed is not a limitation. The lifetime of the relay has been proven by experiment (operating at 50 cycles per second at 3W loading) as >60m operations, with no noticeable loss of performance.

With the high level of signal experienced in the HF environment and the high performance demanded of switching circuitry, a solid state switch was (until recently) considered an unacceptable compromise. Now, Raven Research has solid state designs for HF switching, in which the compromise on isolation, insertion loss and intermodulation performance makes them acceptable (at last) for high dynamic range applications. However, because of the low loss of the relay, it might still be the preferred solution for many applications.

To address the concern of switch contact lifetime, a software package for monitoring was developed. The software package enables the usage of each relay to be monitored. Every connection configuration has a unique storage location in memory and each time a connection is made the storage location is incremented by 1. Using pre-defined limits, alarms can be raised when the planned lifetime of the relay is approached and a replacement board fitted. The usage tables generated by this software can be down loaded to a separate PC at any stage or on a regular basis to form part of a regular maintenance approach.

6. Power Supplies

The primary power supply for the RR1003 SEU is 24Vdc. However, Raven Research developed a 240/120Vac 50Hz switch mode power supply module for the unit, which has sufficiently low RFI/EMC characteristics, as to allow the module to be located inside the unit equipment frame. Thus there is no measurable difference in noise level across the operating band, either with or without the 240V unit. The module has been in-service for 5 years and shows no degradation of performance of the system. The primary power supply for the RR1401A Switching Unit is also +24Vdc and a similar mains power supply module is now available for this unit. This mains powered option is very convenient in some applications.

The RR1815 is a multi-redundant, hot standby 24Vdc Power supply unit, with primary mains power of 240Vac. This power supply incorporates up to 6 separate 24V 10A modules in a load sharing configuration designed to offer N+1 or N+2 redundancy operation.
The unit features automatic fold-back at modular level in the event of a module failure.
For historical reasons, the production modules in service are of a linear design (originally thought to be necessary to eliminate RFI from a switch mode circuit!), so efficiency is about 50%. However, a switch-mode option based on the above can be supplied.

We would propose the use of the RR1815 as an option in Matrix 1 and 2, because the power supply in the master SEU would otherwise represent a single point of system failure. Alternatively, a separate power module in each unit spreads the risk in a similar manner.

The total dc current that is required for Matrix 1 is 50A at 24Vdc.Thus a single RR1815 can be used in N+1 redundant mode, if necessary.

7. Reliability and Maintainability

7.1. Reliability

System reliability is maximised by the following design features adopted for all Raven Research units and systems.

- Use of critical components (e.g. RF power transistors) well below their maximum rating;
- Provision of fan cooling within equipment cabinets and sub-racks;
- Use of modules and subsystems of proven design and reliability (for example HF amplifiers and switching modules);
- Design and development of software using formal methods. This is to maximise the reliability of the control system.

The experience of Raven Research with similar systems already in service has shown that a typical MTBF for a system of the same complexity as Matrix 1 is in the region of 8500 hours. In the rare event of a failure, system availability will be maintained at a high level by the following key features.

- The inherent redundancy evident in the modular design of the system.
- Extensive fault monitoring throughout the system with visible fault indication at modular and sub-assembly level producing very low Mean Time to Repair.
- Direct replacement of modules ‘in-situ’ without the need to power down the unit effected so minimising the disruption to the rest of the system.
- Provision of fall-back paths and back-up facilities to overcome catastrophic failure, for example loss of remote control.

7.2. Maintainability

All this equipment has been designed with ease of maintenance in mind. The majority of hardware faults are detected by built in status circuitry within individual units, resulting in the issue of appropriate fault messages to the remote controller, as well as local fault indications on unit front panels and individual modules. This approach ensures that faults are traced through to the unit and modular level in a very short time.

System repair philosophy is based on replacement of modules and subassemblies, without the need to remove power from the unit affected. Once a faulty module has been identified, usually by observing the front panel status indicator, it is simply a case of removing the module and replacing it with a spare. There is no need to disturb the overall unit or remove power from it during this operation, so that the rest of the system can continue to provide full performance.

The common module approach to unit design means that only a very small number of modular assemblies have to be held as spares, for example power supply modules, HF splitter/switch modules and control PCBs. There are no select on test components or module adjustments required and no requirements for special test equipment for maintenance.

A list of spares recommended for indefinite long term support of any proposed system is given on demand and can best be included in the schedule of initial deliverables for the project.

8. Expansion Capability

The in-service life of the equipment is often expected to be 15-20 years and will probably result in changes of role and system configuration requiring simple expansion of equipment without the need for major re-engineering.

The modular design approach adopted for all Raven Research units facilitates such expansion, both in terms of inputs and outputs.

For example Matrix 2 can be expanded to provide 128 outputs if required by the incorporation of extra RR1003 units and an RR1151 four-way multicoupler or similar. Expansion of the HF inputs can also be achieved by adding extra units, including the RR1401A, configured for 16 x SP4T instead of 32 x SP2T switching.

9. Documentation and Support

The normal level of handbook documentation for the proposed equipment is that based on a modular maintenance policy. At this level, information is provided to assist in the installation, fault finding, repair and routine preventive maintenance.

The standard modular maintenance handbook for each major unit will have the following content.

Chapter 1: General Description
Chapter 2: Operating Information
Chapter 3: Technical Description
Chapter 4: Installation and Preparation for Special Environments
Chapter 5: Maintenance Information
Chapter 6: Parts List
Chapter 7: Modifications
Chapter 8: Associated Unit Manuals and Guides

In addition, the documentation will include a system manual for each customer defined matrix type, which describes in detail the design and performance of the system and gives details of the bespoke software installed in each master SEU to allow the system to operate as required.

Documentation will also include Acceptance Test Schedules for each unit and each system, together with test results and certificate of conformity for each system.

10. Long Term Support

The equipment proposed is warranted for a period of twenty-four months from the date of despatch, to conform to the specifications and to be free from defects in workmanship and materials. The obligation of Raven Research under this warranty shall accordingly be limited to the repair or replacement of equipment or parts covered by the warranty, which prove defective during the warranty period. No credit allowances or replacements will be affected until alleged defects are established to the satisfaction of Raven Research by tests and inspections performed at our facility. Risk of loss of goods sent to Raven Research for repair shall remain with Raven Research only if the company has been notified 7 days in advance of the consignment. Where items are shown not to be defective, reasonable costs of inspection and testing shall be for the account of the customer.

After the warranty period, the company undertakes to repair or replace the equipment at reasonable commercial prices for a period of 10 years, by a process of stocking of parts or post design activity to provide a form fit and functional replacement for a broken or defective part. The choice of support measure is to be at the entire discretion of Raven Research Limited.

10.1. Component Level Maintenance

The equipment proposed could quite practically be repaired to component level by previously trained and skilled technicians. The circuitry is largely designed using discrete components and most circuits are hand assembled in the Raven Research facility. However, no customer has (as yet) put component level maintenance facilities in place for the following reasons.

a) The cost of putting full technical information in place and maintaining the library of parts and circuits will be high compared to the capital cost of the equipment.
b) The cost of maintaining the skill level required is high for such specialised equipment.
c) The number of equipment failures is very small (less than 0.5% of modules deployed per year) and the inherent redundancy level in these systems is very high.

Raven Research therefore recommends a modular maintenance policy throughout.

10.2. Long Term Maintenance Prospect

Generally, the RF circuits are very durable and relatively easy to replace and upgrade as required. They have a low failure rate, are easily repaired in the Raven Research Ltd workshop. Raven Research Ltd can easily re-design form, fit and functional replacements, as and when components become obsolescent

A little caution is needed when dealing with the control subsystem. It is based on the current industrial microcontroller technology which is developing fast. Major system operators should plan on a significant upgrade of the control subsystem every 5 years. This might involve replacing control modules and software upgrades in line with developing industry standards. Experience shows that a typical upgrade costs about 10% of the original equipment price.

11. Installation and Commissioning

The proposed equipment is offered as complete systems, fully tested as systems before shipment from the Raven Research facility at Padworth, England.

If the customer decides to complete the installation, using his own in-house resources, the equipment will not usually be installed in 19” racks. Instead, the system will be shipped as a series of black boxes, ready for rack mounting installation.

A complete kit of parts will be supplied for mounting the equipment supplied into a standard 19” Equipment Bay, conforming to IEC 297 standard, together with a set of control and RF cables, suitable for system proving on the bench when the equipment arrives at the customer’s site.

An in-house system acceptance test procedure, in-house test results and appropriate certification will be supplied. Raven Research will provide all the practical assistance required, to ensure that the final system is installed in the most efficient manner.

If the customer wishes Raven Research Ltd to complete the installation and commissioning, the equipment will usually be pre-installed in 19” racks at the factory and tested as an installed system.

A system acceptance test procedure, in-house test results and appropriate certification will be supplied. The planned acceptance routine is for the factory system acceptance testing to be witnessed by the customer. In this case formal on-site commissioning is expected to be limited to a functionality test and safety check only.

12. Equipment Supplied

Customer System	Type No.	Description	Qty
Matrix 1	RR1003	Master SEU	1
	RR1003	Slave SEU	3
		Extendable Slides (pair)	4
	RR221H	RF Power Splitter	32
	Mounting Panel	1 for 16 pieces RR221H	2
	RR1401A-2T	Switch Unit	2
	RF Interconnect Cable	Splitter to SEU (1m)	64
	RF Interconnect Cable	SEU to Switch Unit (1m)	128
		Control Interconnect Box	1
	Control Cable	Master SEU to box	1
		box to slave SEU	3
		box to Switch Unit	2
Matrix 2	RR1003	Master SEU	1
	RR1003	Slave SEU	1
		Extendable Slides (pair)	2
	RR221H	RF Power Splitter	16
	Control Cable	Master to Slave SEU	1
	RF Interconnect Cable	Splitter to SEU (1m)	32
	Mounting Panel	1 for 16 pieces RR221H	1
Matrix 3	RR1003	Master SEU	1
		Extendable Slides (pair)	1
	Running Spares	(see Annex 2)	

13. Optional Equipment

Customer System	Type No.	Description	Qty
Matrix 1		19” Equipment Bay	
		Mains Distribution Unit	
		Rack Cabling	
	RR1815	Power Supply Unit	1
	RR1846	Active Isolators (16 per unit)	4
Matrix 2		19” Equipment Bay	
		Mains Distribution Unit	
		Rack Cabling	
	RR1846	Active Isolators (16 per unit)	4
Matrix 3	RR1846	Active Isolators (16 per unit)	6
		19” Equipment Bay	
		Mains Distribution Unit	
		Rack Cabling	