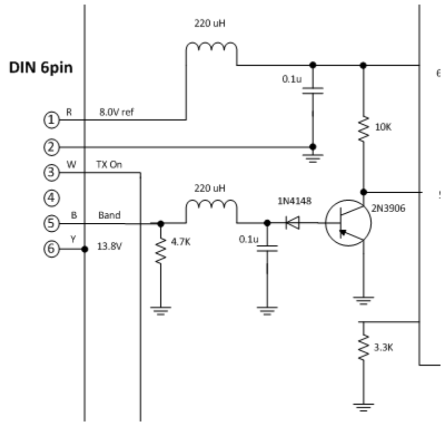
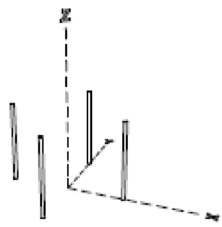
Design Report – Regional HF Station Design
Version: 21 November 2016





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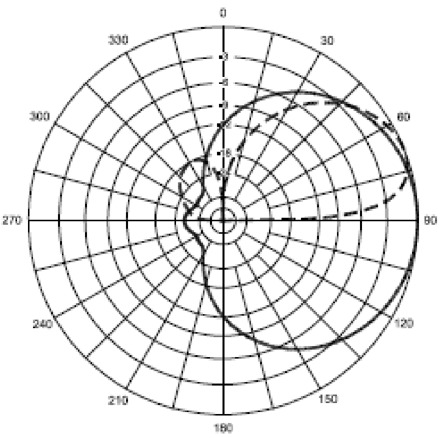

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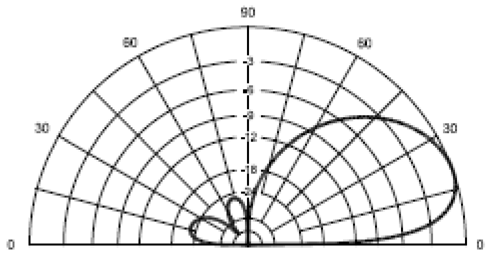

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CONTENTS

Remote HF Station Drawing List

Definitions:

Bespoke: Custom made for a unique purpose. i.e. it is not a common standard item.

COTS: Complete off the Shelf. Usually means a commercially available unit of equipment.

Fuse Discrimination: means selecting fuse values where it's fusing current will not damage or "blow" any fuses upstream of it.

Fuse Rating: means the maximum current the fuse can carry without blowing. This is different from the fusing current when it melts. Rough rule of thumb fusing current is about double the rated current.

Remote Control: is the control part of SCADA

SCADA: System Control and Data Acquisition. This is also called remote control and supervisory system.

Supervisory: is the Data acquisition part of SCADA

Remote site: The location of the remote HF station's antennas and transmitting equipment. (i.e out of town site)

Base node: The primary location of the base from which the remote HF Station (site) is controlled. In the event of multiple share users it is envisage that session sharing and management would also be controlled at the Base Node.

Purpose of this document

This document is a Design Report on the Wellington Regional HF Remote Station being built by the Quartz Hill User Group of WARC

Design Philosophy

The design approach has been to plan for a number of self-contained and autonomous modules (boxes) that are interconnected to achieve the overall functionality of the station.

Where a more integrated approach to the design might be argued as more economic, this has been resisted in the interests of making the system simple to understand and allowing modules to be built individually and tested thoroughly by themselves before interconnecting with associated system modules.

Where possible all modules used are Complete-Off-The-Shelf (COTS) commercial units. Examples of this are Power supply Inverters, Voltage bucks and Solar Regulators.

There are custom modules still required though to interconnect COTS equipment and to interface it to the SCADA (Remote control and supervisory). These are duplicated within the system where possible to allow easy swap-out for fault isolation. Otherwise spare units of these bespoke modules must be provided for the operational station. In addition a very detailed level of documentation (circuit diagrams, as-built drawings etc.) is deemed essential for all bespoke items.

Guiding principle: If you need a bespoke module that is mission critical, then you must build two of them and produce a detailed service manual!

Interconnection Cable Guide

SCADA

All interconnecting cables between modules are usually male to male where the connector types are the same on each end. Exceptions to this may be when different connector types are being used at each end of an interconnecting cable.

This means all connectors on the various modules are female. The preferred connector types are DIN 6 pin, DB15-15 pin, DB25 – 25 pin, and DB 37 – 37 pin for interconnections.

For potentially long cable runs such as external interconnection with antenna selectors or 4 square phase switching boxes, the preferred cable is cat 5 or 6 data cable with RJ45 connectors. Again male to male connectors on the interconnecting cable.

RF Coax Cables

At power levels of 100 Watts RF and below: Impedance is 50 Ohms and connector type PL259 is preferred. All cables male to male.

Low power levels of RF for samplers or monitors impedance is 50 Ohms and connectors should use Type BNC or RCA (audio) connectors

At power levels of above 100 Watts (and nominally 1000 Watts RF), impedance is 50 Ohm and the connector type must be type N. All cables must be RG 213 male to male.

The Phased Array branch feeders (4 each) used on the a square antennas are tuned lengths of 75 Ohm cable. The connector types are chosen to suit the cable used:

F Type if low cost 75 Ohm TV cable such as RG 7 is used

N Type if high power 75 Ohm cable such as RG 11U is used

Power System

Grid versus Solar Power

The power system is designed as an “off –grid” solar powered arrangement. The advantages seen at the time of designing the system were:

1. The final location of the station was unknown at the time of developing the equipment therefore availability of 230 Vac was uncertain.
2. The station is to be operable in the event of a regional disaster when the 230 Vac grid power might not be available.
3. Such power autonomy avoids the ongoing line charge and consumption costs for a 230Vac connection.

Design Capacity and Voltage

A primary rail of 24 Volts with 600 Ah batteries has been selected based on available batteries and commonly used hardware for off grid systems, and the likely initial load profile.

The suggested charging capacity is to use four 250 Watt Solar panels and two STECA Solar Charge Controllers that will supply during sunlight: up to 40 amps at 24 Volts to the 600 Ah batteries.

Initially the system may work with only two x 250 Watt panels if the duty cycle of the station is low enough to permit this. If a heavier duty cycle transpires then more solar panels and regulators could be added. The maximum short term charging current for the 600 Ah batteries is 60 Amps RMS and the steady longer term charging rate of 30 Amps rms are the figures recommended in the Sonnenschein battery manual.

Solar Array Regulators

Two STECA Solar Charge Controllers (Model PR2020)are configured as Chargers only and no connections are made to the load terminals of these units. This means there is no load condition metering in operation with these units.

The Outputs of the two regulators are connected in parallel (via 20amp fuses) across the battery.

It is essential that the connections to the 24V solar panels (i.e. the inputs of the two regulators) have no common connection. Meaning also that no inputs connections or solar panel supply leads are allowed to be earthed.

The purpose of the 20 Amp fuses in the positive leads of the regulators is to protect against excessive current flowing back from the battery in the event of a short occurring within the regulator. They also provide an easy means of disconnecting a regulator from the battery.

Fuse Table

Circuit Name	Fuse Rating	Typical Peak Amps	Fuse Type
Battery Primary	200A	160A	Stud Link
Inverter 1 - 24V to 230V ac	100A	80A	Stud Link
Inverter 2 - 24V to 230V ac	100A	80A	Stud Link
Voltage Buck 1 24V to 12V DC	20A	10A	Auto motive STD Blade
Voltage Buck 2 24V to 12V DC	20A	10A	Auto motive STD Blade
SCADA All	5A	1A	Auto motive STD Blade
Ancillary 24V	5A	-	

Bill of Materials - DC Power Supply System

Item	Description	Each	Approx Cost
1	0 gauge battery cables 2.5metres	2	$250
2	Fuse link 200A	1	$10.90
3	Fuse link 100A	2	$21.80
4	Fuse Link 80A	1	$10.90
5	Automotive Blade 6 way Fuse Box	1	15.90
6	Automotive Blade Fuses (1.50ea)	6	$9.00
7	STECA PR2020 Solar Regulators	2	$317.60
8	24V to 230Vac inverter 2 Kw ($280 ea)	2	$560
9	24V to 12V DC Voltage Buck 45Amps ($105.90 ea)	2	$211.80
10	Nuts Bolts Screws	20	$10
11	Acrylic Sheet	2	$10
12	PVC Sheet	2	$8
13	Copper Bus Bars	4	
	Total:		**$1439.90**

Sonnenschein A600 Gel Batteries or equivalent.

LxWxH - 168x208x513 mm
Weight - 42 kg
Nominal Voltage - 2V

New Price = $800 per 2V cell. Specified = life 20 years
24volt Bank new price = $9,600

10 year old batteries supplied. 50% life value = $4,800.

24 Volt DC Distribution Panel

A comment on Fuse ratings and discrimination:

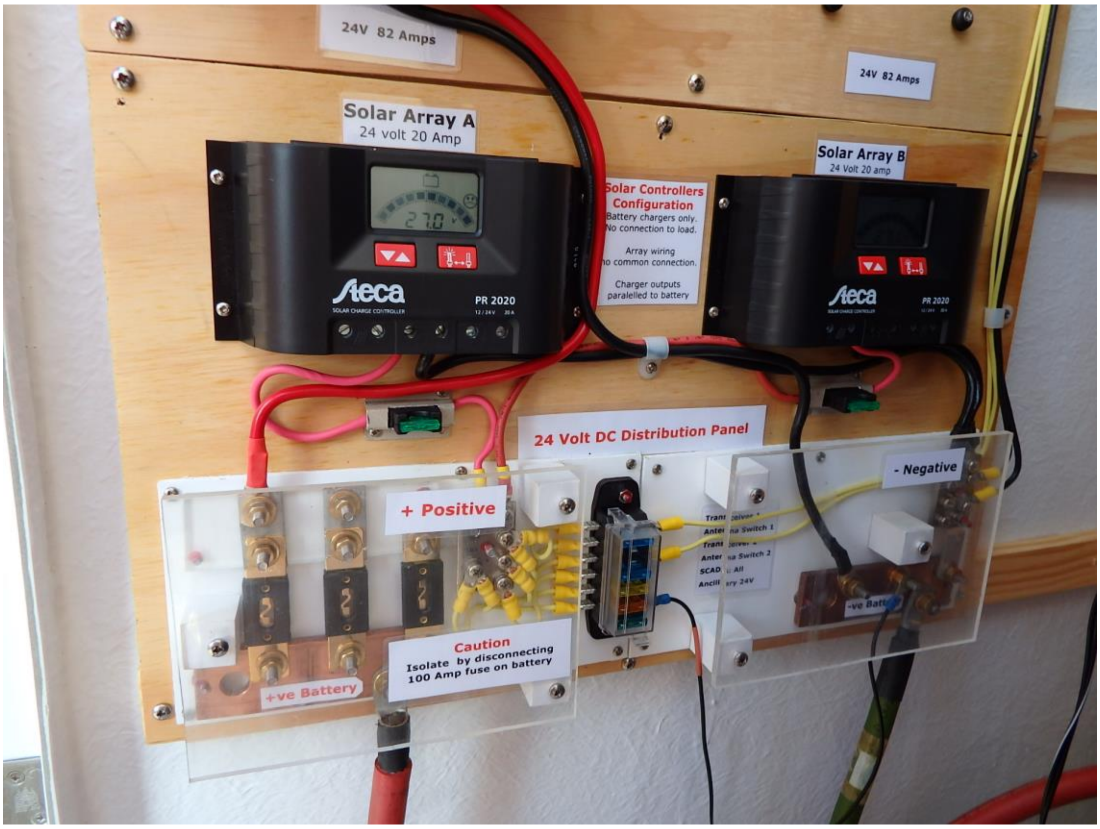
The purpose of any fuse link is to protect against a dangerous level of fault current in the event of a short circuit occurring anywhere in the power system.

A fuse link supplying a module of equipment should operate at about 75% of its marked rating. For example if the 24V to 230Vac inverters need about 75 Amps at peak operation then they should be supplied with 100Amp fuses.

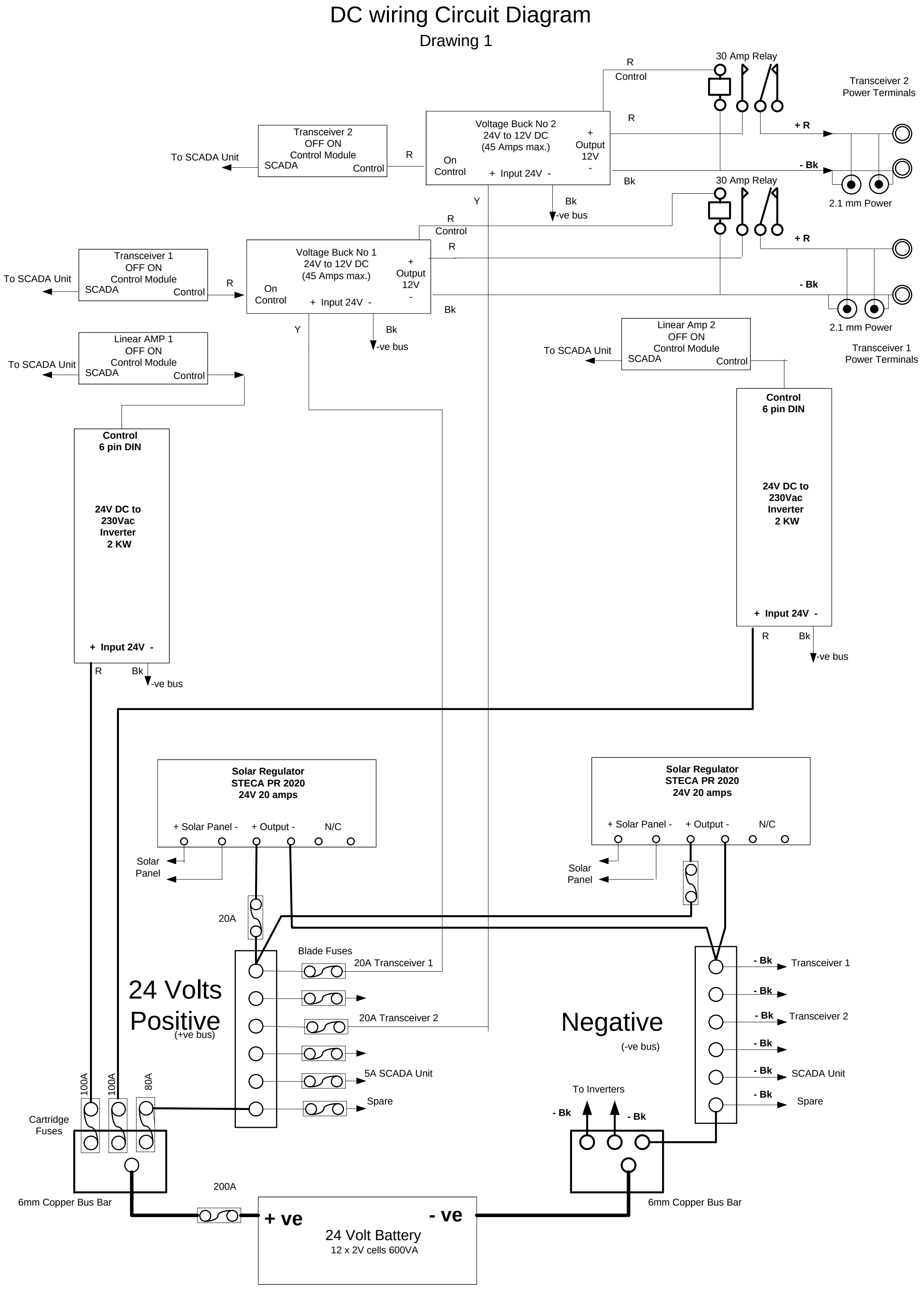
Fuse size discrimination means selecting fuse values where it's fusing current will not damage or "blow" any fuses upstream of it.

Rule of thumb: A ratio of 1:2 is the minimum that should be used for simple copper fuses. For example if the 24V – 230Vac inverter fuses are set at 100 Amps, then the upstream battery fuse should be rated at least 200 Amps.

At the lower current fuse levels greater ratio than two times should be aimed for. For example the 24 V supply feed to the 24V to 12V bucks are 20 amps while the upstream fuse feeding the bus to the fuse bank is 80 Amps thereby giving a good discrimination ratio of four times.



DC Wiring Diagram



Remote Control of the power circuits

There is a requirement to be able to turn various circuits “on” or “off” by remote control. To facilitate this interfacing modules have been designed that need an “on-pulse” from the SCADA to activate a circuit and an “off-pulse” to de-activate.

The modules that are controlled in this manner are:

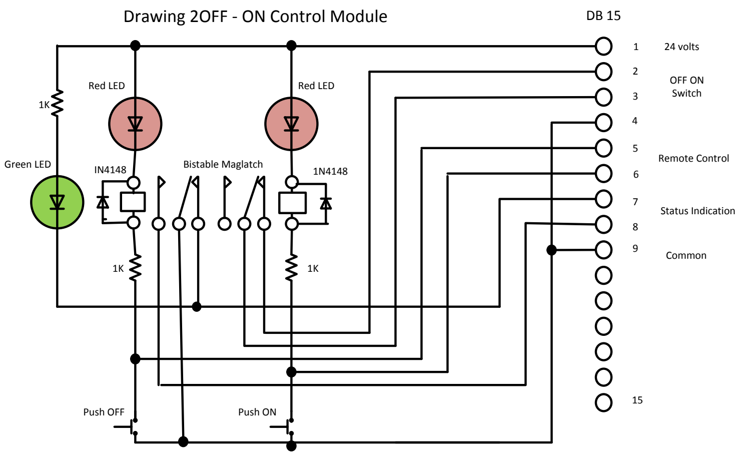
24 V to 230 Vac Inverter 1

24 V to 230 Vac Inverter 2

24 V to 12 V buck 1

24 V to 12 V buck 2

A similar pulse concept is also used for remote control of the antenna selector and antenna directivity switching.



Bistable Maglatch: DPDT PCB Mount Latching relay. RS part No: 515-571

Circuit Description

The purpose of this module is to allow the controlled equipment to which it is connected to be locally or remotely operated. There are four identical modules for the station.

The off-on functions are controlled by a bi-stable magnetic latch relay. In one position the relay is in the “off” position and in the other position: “on”. The bi-stable (maglatch) relay “remembers” the most recent command received.

Commands are a short pulse, (momentary ground) that comes from either the local push button switched on the unit or from the station’s SCADA.

The actual control outputs are on pins 2 and 3 and can be configured using the closed contacts as the “on” condition and open for “off”. These relay contacts are rated at 5 Amps.

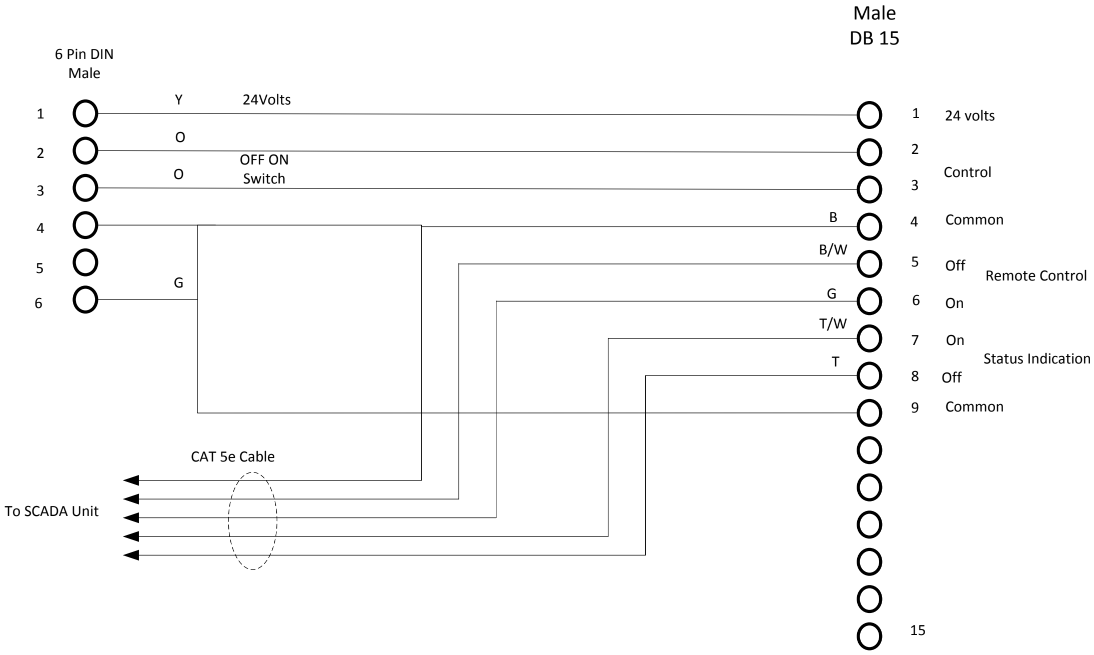
Bill of Materials - Remote On-Off Interface

Item	Description	Each	Approx Cost
1	Enclosure - Jiffy box UB5 Flanged	1	5.90
2	Push Button Switch	2	2.00
3	LED Red	2	1.00
4	LED Green	1	0.50
5	DB15 Female	1	2.50
	DB15 Male free	1	2.50
6	Diodes 1N4148	2	1.00
7	Resistors 1k	2	1.20
	Bistable Relay	1	7.00
	Total:		**23.60**

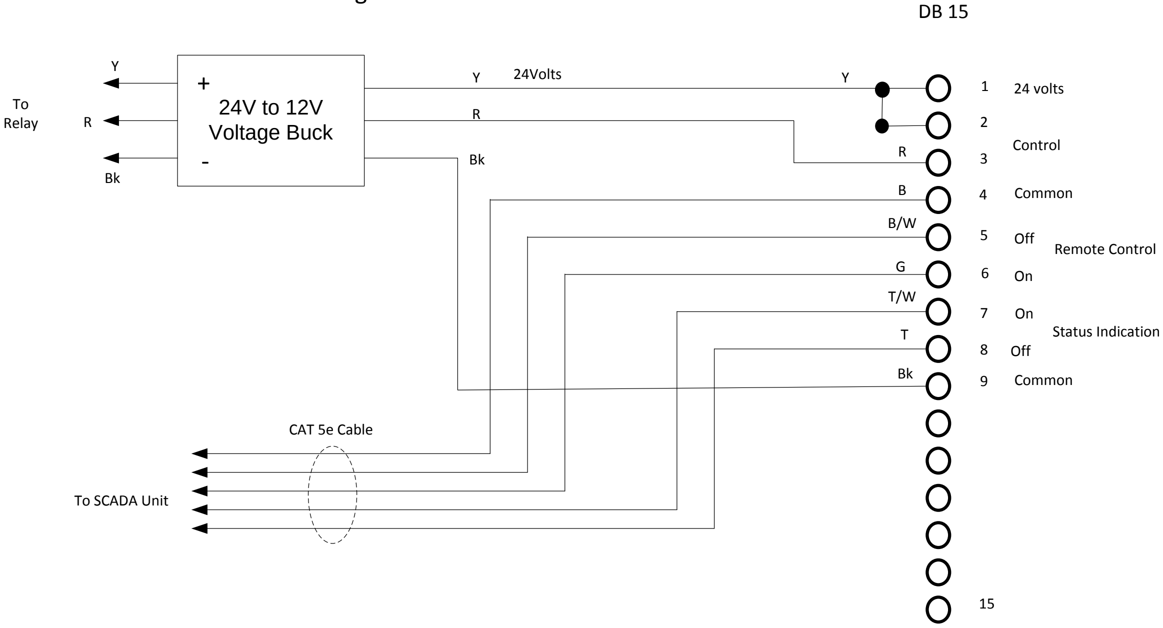
Inverter and Voltage Buck Cable Pin-outs

Drawing 3 Cable Loom for OFF - ON Control Module

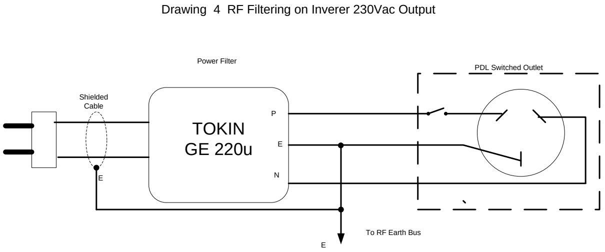
24V to 230V Inverter Connections



24V to 12 Voltage Buck Connections



Mains Filtering on Inverter 230 Vac Output
Drawing 4



Environment Conditioning

In an ideal situation, the type of equipment used for this station is best housed in a building sealed from outside air moisture and would use a heat pump to extract any surplus heat from the enclosure. While this approach would keep the equipment very clean and dry the expense of this plant and the potential power consumption of such a system rules out this approach.

A low cost and efficient heat extraction system is to reticulate sufficient outside air through the enclosure to prevent over heating of the equipment in operation.

The quiescent dissipation is estimated to be less than 50 watts and should require no forced air extraction. However depending on the transmitting duty cycle, a sufficient volume of air needs to be moved through the enclosure to extract heat of say 2 kW during peak dissipation.

The challenge with fresh air cooling is to ensure good filtering of the intake air and regular air filter maintenance is carried out to prevent premature deterioration of the equipment in the enclosure.

The following assumptions are made:

Minimum enclosure temperature: No lower limit. No heating control.

Maximum Enclosure Temperature: Alarm Condition: 40^{o} C

Target Temperature Range 20 - 25^{o} C

Heat extraction

Hot air is extracted by thermostatically controlled 24V fans installed in the extractor cowl in the top of the entrance door. These would probably be set to turn on at 25^{o} C. This could be reconfigured to a two stage system with half the fans coming on at 25 ^{o}C and the other half turning on at 30 ^{o}C if this resulted in energy conservation (in the power to run the fans).

Cool air is filtered at the air intake cowl mounted lower in the same door. Consideration should be given to fitting an electronically controlled louver on the air intake if control of the lower temperatures is required. Commercial units commonly used on air intakes for diesel generators could be sourced. These operate on 24 Volts and could be set to close when temperatures drop below say 15 ^{o}C

Being thermostatically controlled means the running cycle of the fans will be dependent on the transmit duty cycle of the transceivers and linear amplifiers within the enclosure. This is expected to result in efficient and relatively low consumption of the station’s power supply.

Humidity alarms and temperature alarms are provided and are completely independent of the fan and louver control. These alarms connect to the SCADA.

Radio Equipment

Operational Overview

The station is designed to have two transceivers and their associated 1 kW linear amplifiers capable of being independently and simultaneously operated by remote control on bands that are pre-assigned to them.

The transceivers are inhibited from both using the same bands at the same time for transmitting. This is achieved by simply assigning a few bands to one transceiver and different bands to the other.

Transceivers

The initial design is based on Icom Transceivers capable of up to 100 Watt that are used to drive each ones associated Daytron Linear Amplifier.

There is an automatic antenna tuner installed between the Icom transceiver and the input to the linear amplifier. This is not really necessary when the linear is being used, but is more likely useful when the linear is bypassed and 100 watt operation is envisaged.

Daytron 1kW linear Amplifier

The Daytron Linears are a solid state robust military spec device that that do not need tuning. They do have band switched filters that need to be pre-selected for the intended band being used.

The ICOM Radios provide a band dependent voltage output on pin xx of the ACC socket that is applied to the ICOM Band Switch Interface Unit. This in turn selects the correct operating band of the Daytron Linear. This is a type of A to D converter.

There are slight variations in the band voltages between different ICOM radios. Some adjustments may be required to the interface to suit some different radios.

In addition to the band switch interface this unit has band inhibit switches that allow any bands to be prevented from turning the linear amplifier on. This TX inhibit function is not remotely controlled. It is used for example to prevent a band being used if there is no antenna available for that band. This must be set up on the remote site as per the prevailing antenna availability.

Band Selector and Linear Amp Interface

The design for the Band Interface Unit has been adapted from one developed by Bob Wolbert K6XX (1997) This is presented in Drawing 6

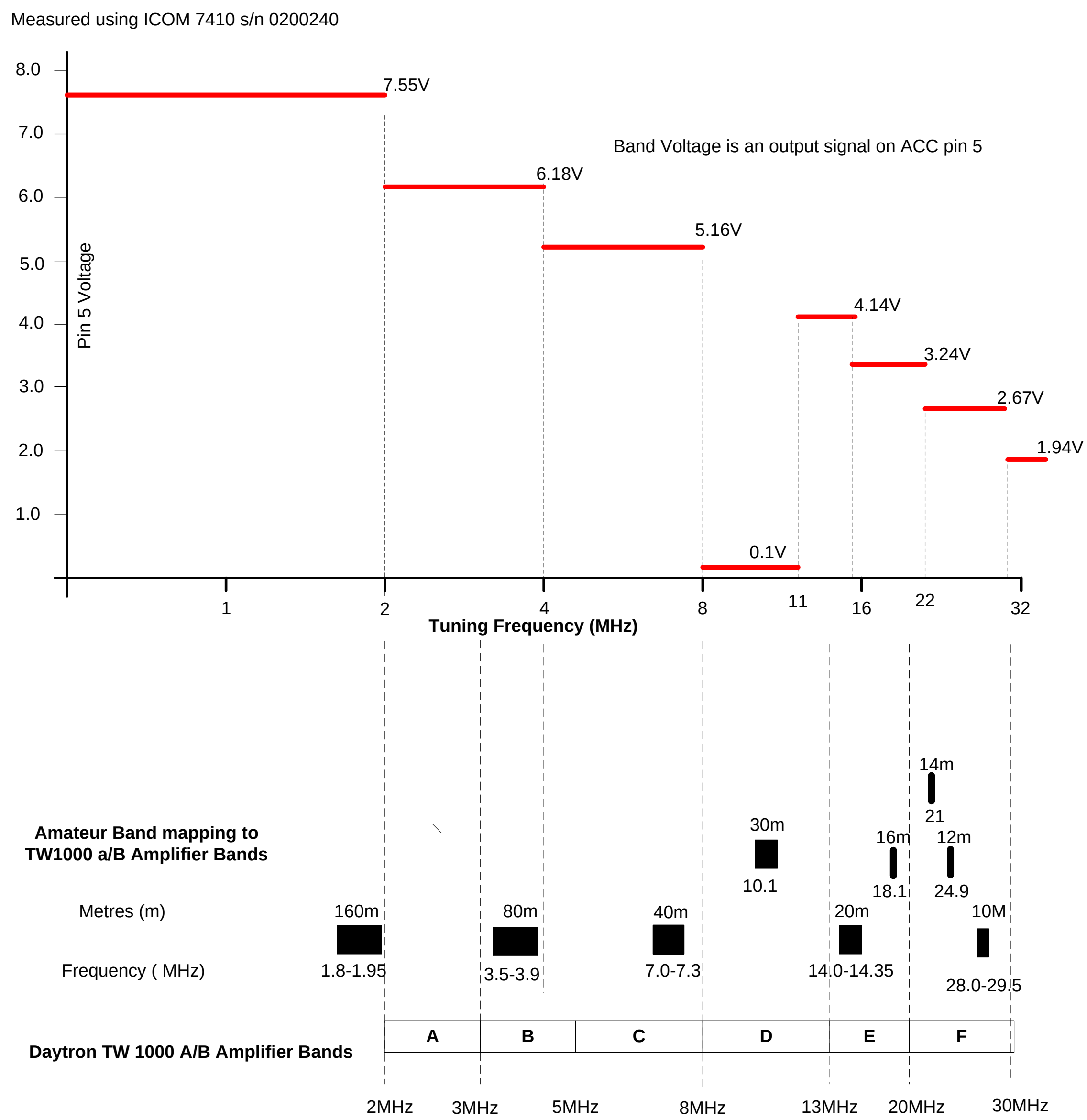
The interface Unit has two parts:

1. The A to D converter that uses a LED bar graph meter driver (LM3914) and a line up of robust PNP transistors that switch the Linear amplifier filters.
2. A PTT control that uses the ICOM PTT output to turn on the Linear Amplifier. This part of the circuit has the switches to enable or inhibit the TX On command reaching the TW1000 A/B Linear Amplifier.

Drawing 5 ICOM IC 7410 Band Voltages:

This picture shows how the IC 7410 band voltages map to the bands available in the Datron TW 100A/B Linear amplifier. In Table form the data is:

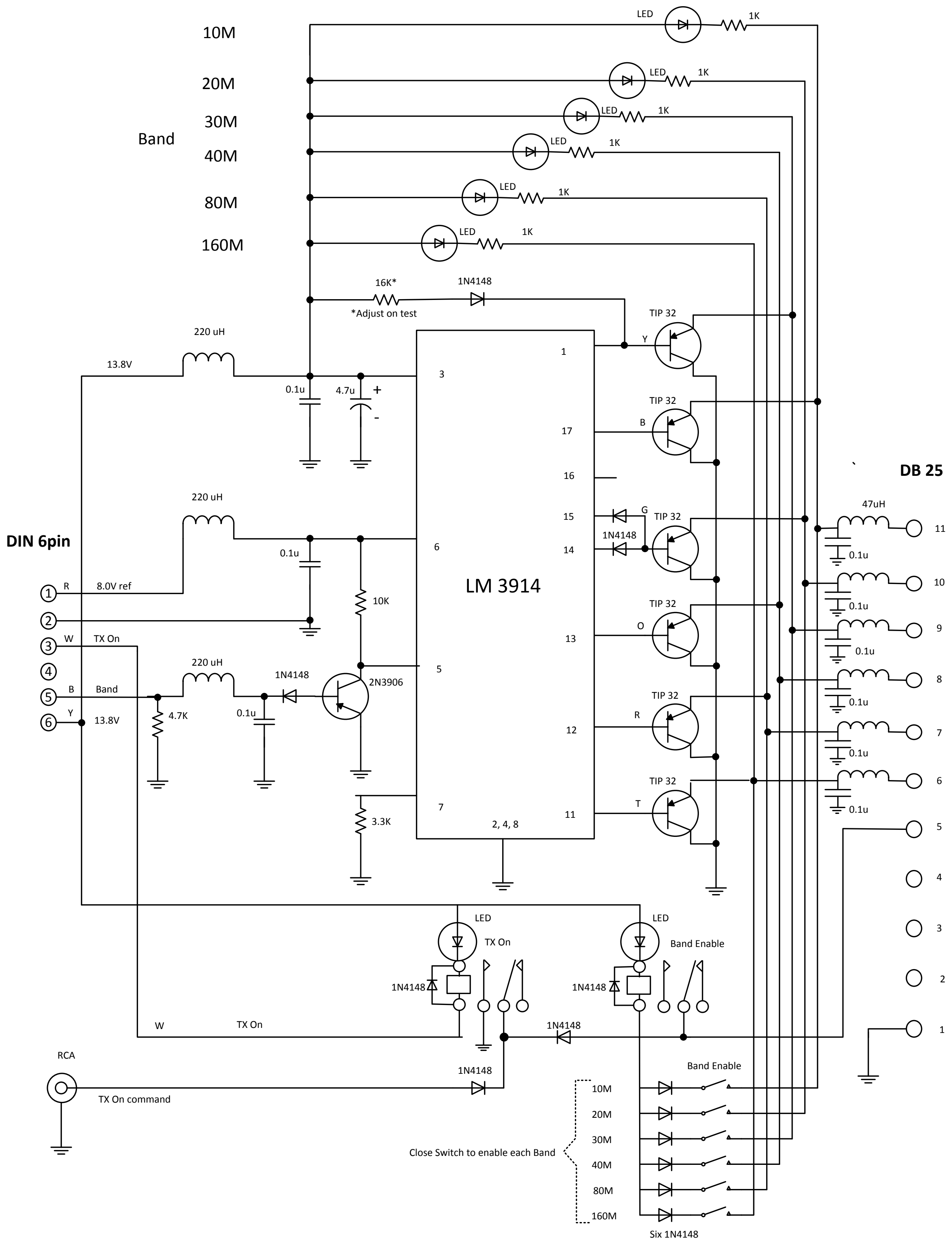
Drawing 5 ICOM Band Voltages



Band Label	Linear Band	ICOM Frequency	Linear Frequency	ICOM 7410 Voltage
160	A	1800 - 1950	2 - 3 MHz	7.55
80	B	3500 - 3800	3 – 5 MHz	6.18
40	C	7000 - 7300	5 – 8 Mhz	5.16
30	D	10100 - 10150	8 - 13 MHz	0.1
20	E	14000 - 14300	13 – 20 MHz	4.14
20		18000 - 21450	13 – 20 MHz	3.24
10	F	24890-29700	20 – 30 MHz	2.67

Band Selector and Linear Amplifier Interface

Drawing 6 Band Selector and Linear Amp Interface



Bill of Materials – ICOM Band Select interface Unit

Item	Description	Each	Approx Cost
1	1H Rack Unit Tray low cost home brew	1	$5
2	RF chokes 47uH	6	$6
3	LM3914 At o D converter (bar graph meter driver)	1	$9
4	18 Pin IC Socket	1	$1.
5	PNP driver transistors TIP 32	6	$14
6	Matrix board 40mm x 60mm	1	$3
7	LEDs	6	$3
8	Mini toggle switch (low cost 3.90ea)	6	$23
9	12V Reed relay SY-4032 type SPST N/O ($5.90 ea)	2	$12
10	Reisitors adnd Capacitors	8	$4.00
11	DB 25 pin Female Chassis Mtg	1	$2.50
12	DB15 Male free	1	$2.50
13	DIN 6 Pin Female Chassis Mtg	1	$2.50
14	RCE Female Chassis Mtg	1	$2.50
15	Nut Bolts Screws and Misc Hardware		$5.00
	Total:		**$95.00**

Weak Signal Propagation Reporter (WSPR)

It is planned that a transceiver, antennas, and associated control system for WSPR would be independent of the two operating transceivers.

A WSPR would likely use a multiband antenna (such as a 6 BTV) and not need an antenna switch. A self-contained WSPR may only require a low speed data circuit from the site.

Antenna Selector Switch

An antenna switch is provided for each transceiver on the station. Each selector switch has one input and 6 outputs: one of which is connected to a 50 Ohm load (for testing). This means up to 5 antennas can be connected to each selector switch.

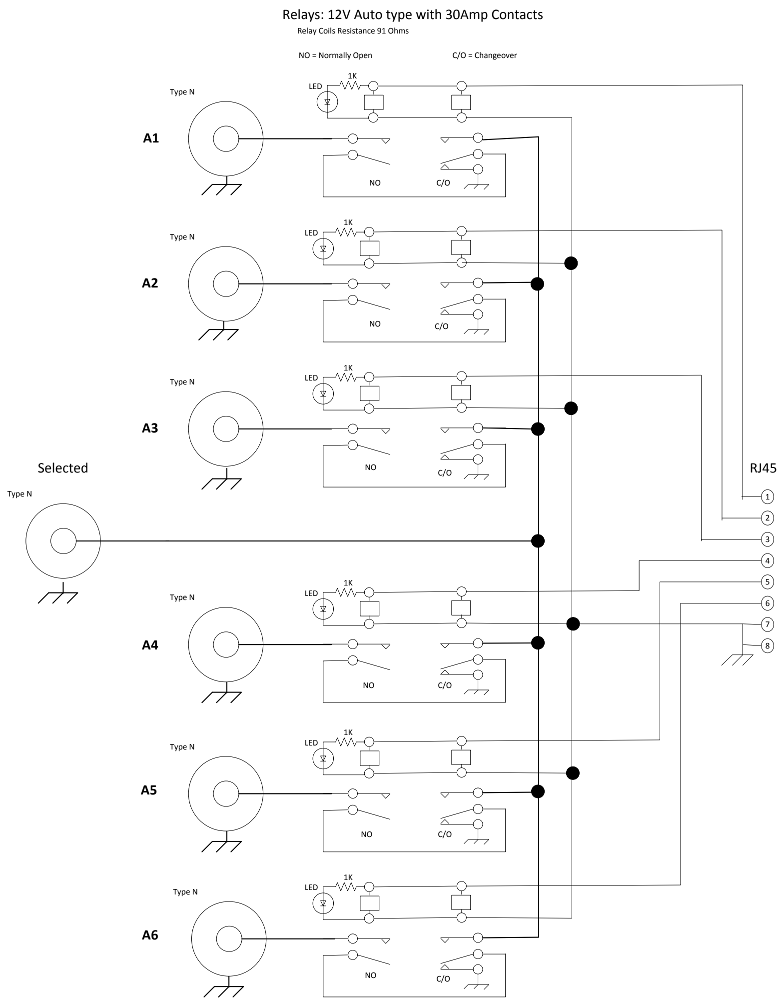
The Antenna selector is in two parts: The part that does the RF switching such as Coax connectors and relays, called: **Antenna Selector Switch**, and the control unit that allows local or remote selection of the relays, called **Antenna Selector Control Unit**:

Bill of Materials for the antenna selector switch

Item	Description	Each	Approx Cost
1	Splash proof enclosure 171x121x80	1	$27.00
2	12v horn relay SPST	6	$47.40
3	12v horn relay SPDT	6	$47.40
4	N Type Chassis MTG Connector	7	$56.00
5	DB 15 Connector female Chassis Mtg	1	$5.50
6	DB 15 Connector male free		$2.50
7	RJ45 Connector female	1	$4.00
8	LEDs and resistors	6	$3.00
9	PCB copper sheet	2	$5.00
10	Nuts and bolts	several	$2.00
	Total:		**$199.80**

Antenna Selector switch circuit diagram

Drawing 7 Antenna Selector Switch



Circuit Description

Each antenna port has two relays in series that are energized when that port is selected by the Antenna Selector Control Unit. One of the relays is a changeover configuration so that the contacts at rest position are earthed. This gives a huge improvement in isolation between ports of -80dB or more. This is because the capacitance between the contacts that would otherwise cause leakage is shorted to earth.

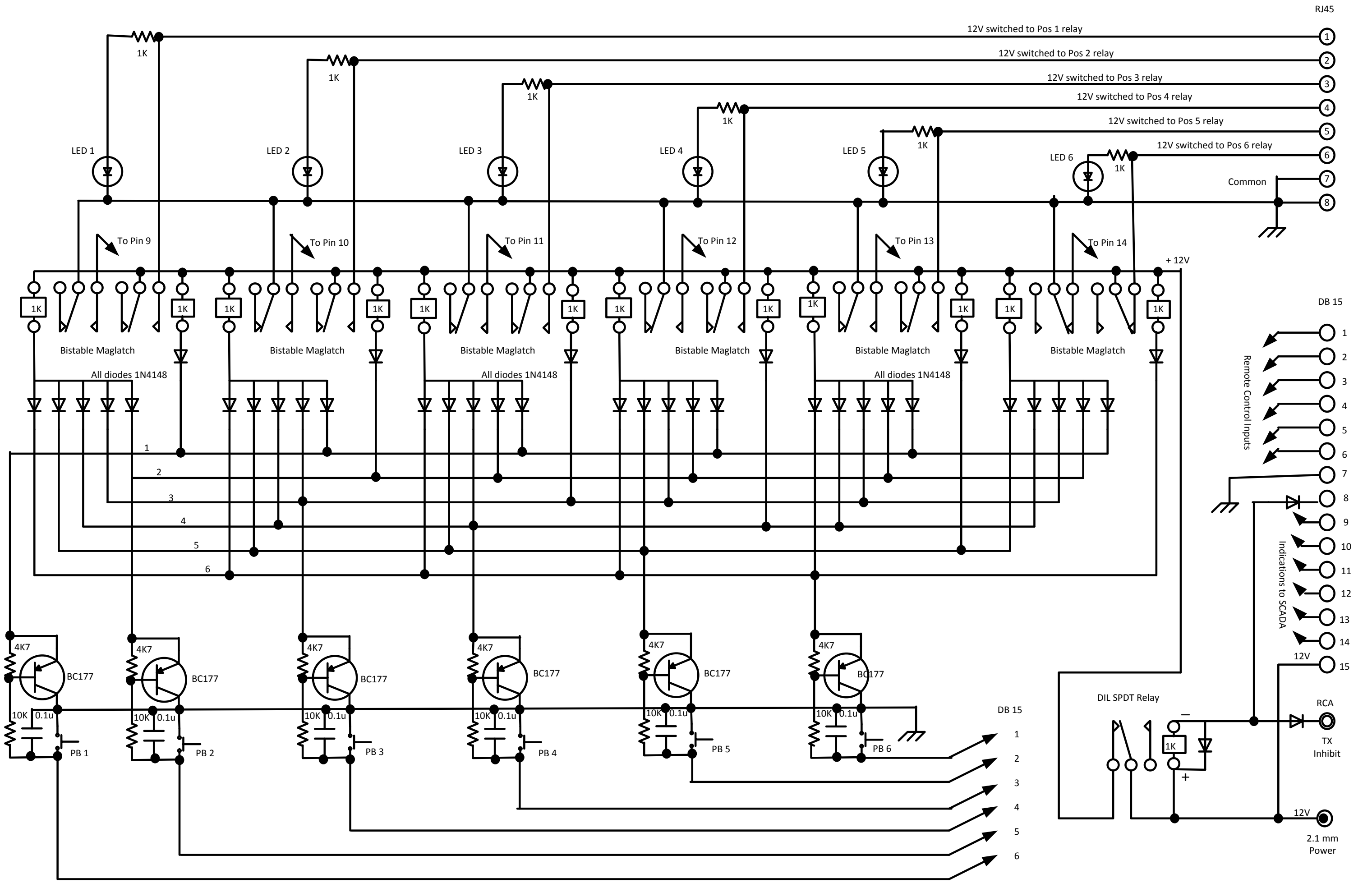
The Antenna Selector Control Unit allows local and remote control of the antenna selector. A momentary push of any one of the six front panel push buttons will select the corresponding antenna. Similarly and alternatively a momentary closing contact (grounding) from the SCADA allows remote selection of the required antenna.

Antenna Selector Circuit

Drawing 8 Antenna Selector Control Unit

Bistable Relays: DPDT DIL PCB Mounting RS Stock number 515-571

Spike suppression diode are fitted across each relay coil but are not shown in the circuit below



Circuit Description of antenna control unit

The purpose of this unit is to allow the six position Antenna Selector Switch to be operated both locally and remotely.

Central to the unit's function are the six interlocked magnetic latching relays. These bi-stable devices "remember" the most recent command that was received from either the local push buttons or remotely via the SCADA. Commands are a short pulse (momentary ground) to select the required antenna.

The purpose of the transistors is to drive the pulse required by the 6 relays (a total of about 80mA) when an antenna is selected. This means the current sinking required at the inputs (or by the local PB switches is therefore only 8mA.

There is a transmitter interlock provided. When the centre pin of the RCA connector is grounded this energizes the TX inhibit relay which removes the power from the other relays in the unit for the duration of transmitting. This prevents the Antenna Selector RF relays being operated during transmissions.

The control cable between this control unit and the Antenna Selector Box is an 8 conductor low cost Cat 5e data cable with RJ45 male connectors. This allows the antenna selector box to be located up to 100metres away from the control unit if required.

The SCADA cable between this unit and the SCADA unit is 15 conductor with male to male DB15 connectors.

Note the standard for SCADA is to always use female DB15, DB 25 and DIN on the equipment units so that all interconnecting cables are male to male.

Details of the actual phase switching to achieve directivity switching is detailed later under the heading **Antenna Directivity Switching** where the operation of the 4 Square Array Antennas is described.

Bill of Materials for the Antenna Control Unit

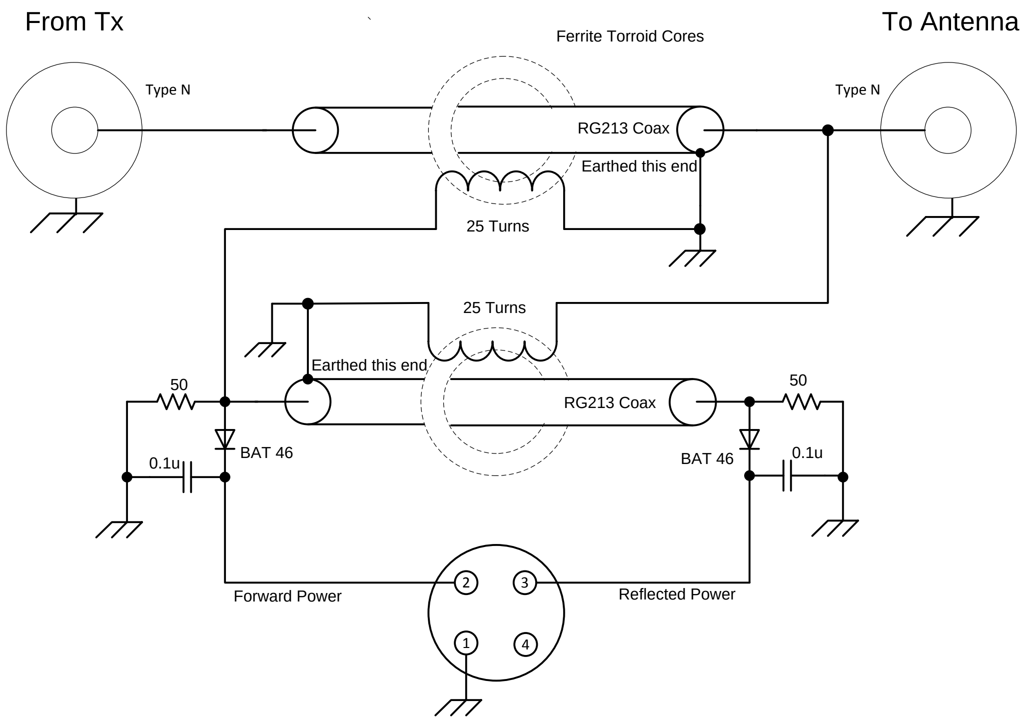
Item	Description	Each	Approx Cost
1	Enclosure Jiffy box UB1 black 158x95x53	1	$5.50
2	Bistable Relays	6	$42.00
3	PB switch	6	$12.00
4	LEDs and resistors	6	$3.00
5	Vero Board	1	$9.90
6	Transistors and resistors	6	$3.00
7	Diodes 1N 914 or 1N4148	56	$ 4.00
8	DB 15 Connector female chassis Mtg	1	$5.50
9	DB15 Connector male free	1	$2.50
10	RCA socket	1	$2.50
11	2.1mm power plug (12v connection)	1	$2.50
	Total:		**$92.40**

VSWR Monitoring

VSWR Bridges are installed at the outputs of the linear amplifiers which is effectively the input to the antenna selector switches. These are rated for 1kilo Watt noting that a useful indication is also expected when the linear amplifier is bypassed (by turning it off). Under this condition the VSWR bridge would be measuring the power out of the ICOM Transceiver which would be a bit less than 100 Watts

The purpose of this VSWR monitor is to indicate the condition of which ever antenna is selected and to indicate the RF Power level at this point. The analogue output of these bridges (indicating both forward and reflected power level) are connected to the SCADA

Drawing 9 VSWR Bridge Circuit



Labelling of different versions:

Model 20T= 20 turns on the torroid cores. Model 25T = 25 turns, Model 30T= 30 Turns

The Analogue outputs for Forward and reflected Power are on a 4-pin microphone socket:

Microphone 4 pin plug and socket pin outs:

Pin	Connection
1	Earth
2	Forward
3	Reflected
4	N/C

Bill of Materials for VSWR Monitor

Item	Description	Each	Approx Cost
1	HB 5040 Diecast Box 115x65x55	1	$22.90
2	Ferrite Torriod cores L8 25x15x10	2	$3.00
3	Microphone Plug female free 4 pin	1	$3.90
4	Microphone Socket male Chassis 4 pin	1	$3.90
5	N Type Chassis MTG Connector	2	$18.00
6	Schottky Diodes BAT 46/48	2	$3.70
7	Resistors 50 Ohm	2	$1.20
8	Capacitors 100nf (0.1uf)	2	$2.00
9	Nuts and bolts	several	$2.00
	Total:		**$60.60**

SCADA

SCADA means System Control and Data Acquisition and refers to the remote Control and monitoring of the station's systems.

The SCADA controls and monitors the power systems, antenna selection and directivity, and the site security and environment. The SCADA system does not include the **Remote Rig** system that controls just the ICOM Transceiver functions of voice and data.

SCADA is easiest dealt with as two separate sub-systems:

> **Control**- also sometimes called: "Remote Control" or "Forward Control". This system is designed with 36 control functions
>
> **Supervisory –** also sometimes called "Site Data" or "Telemetry" or "Status Indications". This system is designed with 36 of these indications

Control Protocol

The control system is designed so that when a command is to be executed, a momentary closing of a contact to ground is required.(Ground Active or Logic "0"). This protocol means an "on" command always has to be a separate command from an "off" command.

This pulse concept for all controls was described earlier under the "Power" section and is repeated here:

For example to turn the power "on" to the linear amplifier (i.e. The 24V to 230V inverter), a momentary grounding of an "on" pin is required (at either end of the remote control system). To turn the linear amplifier "off" a momentary grounding of a separate "off" pin is required. (again at either end of the control system.)

This approach means that the functions subject to remote control can be operated from either the base node or at the HF Site quite independently of each other. The only exception to this rule is the way the Transmit "on" function works. This is described later under **Remote Rig** and **Transmitter Interlocks**

Supervisory Protocol

The supervisory part of the SCADA is designed to monitor the status of many different points in the Station's systems.

Status indications are of a digital nature and require a sustained closing of a contact to ground (ground active or logic "0"). An open contact (high) or logic 1 is the default condition for no indication.

Analogue Indications are provided for RF Power and VSWR for each Transceiver/Linear Combo. This also described under **VSWR Monitors.**

In addition some analogue indications around the Solar Power Generation and primary battery supply Voltage and load current are also provided.

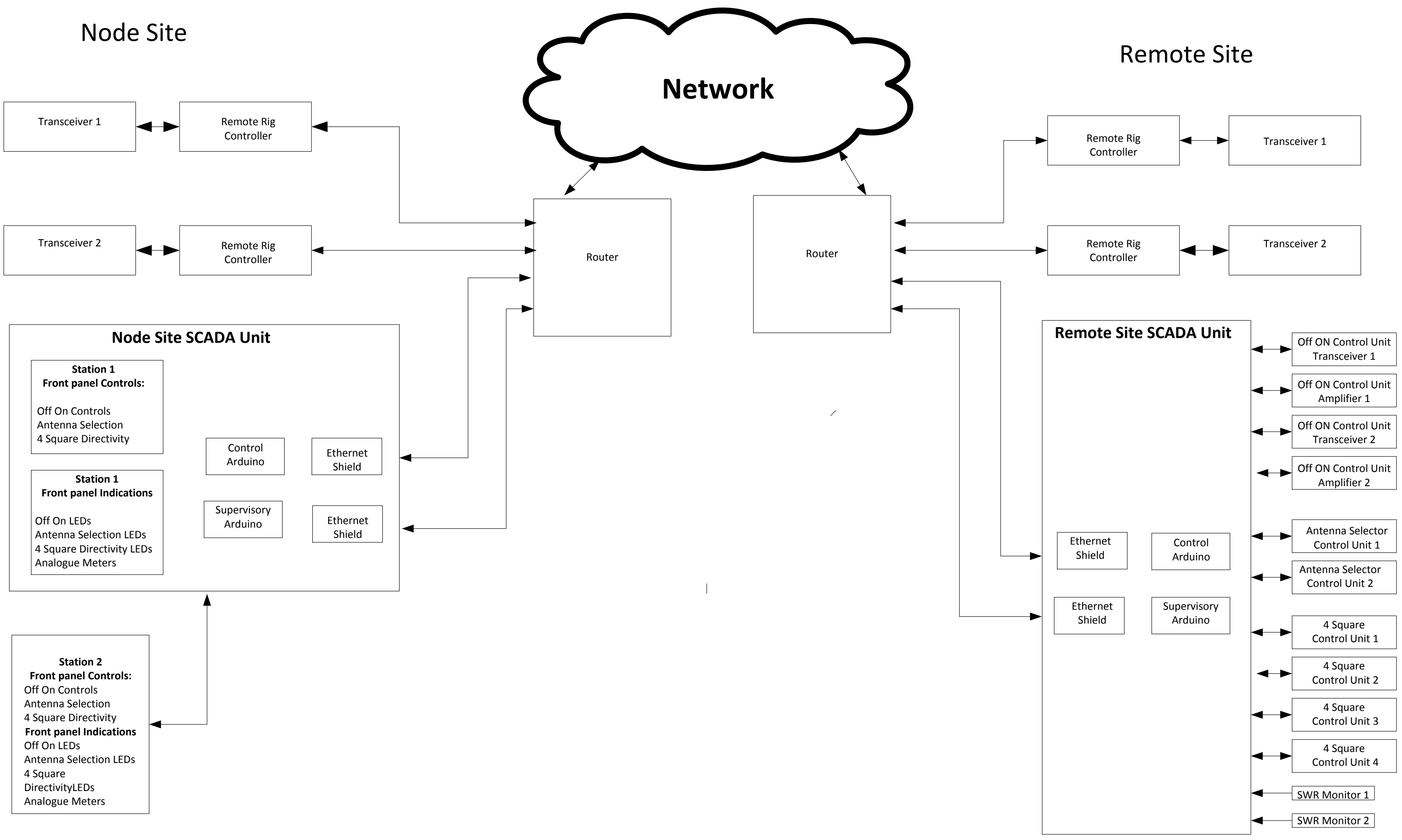
The indications used in this design are based on what an operator would want to see to gain assurance that the station is operating correctly and to assist with trouble shooting in the event of a major malfunction.

Remote HF Station SCADA Design Report

The details of the SCADA design is the subject of a separate design report. This report contains Drawing Numbers 11, 11a, 11b, 11c, 12, 12a, 12b, and 12c

QHUG HF Remote Station SCADA Design Report. The revision number is indicated on the end of the file name as the date in the reverse number format YYYYMMDD

Drawing 10 Schematic of SCADA System



Remote Rig

The Remoterig RRC-1258MkII is developed specially for remote control of Amateur radio stations via the Internet, in a user friendly and cost-effective way.

The Remoterig units are normally used in pairs, one is connected to the radio and the other is connected to the control equipment. The system is unique in the way that no PC is needed, both voice and data communication is handled by the two units.

RRC-1258MkII can be configured to work together with most Amateur radio stations available on the market from ICOM, Kenwood, Yaesu and Elecraft.

You will get the ultimate function of the Remoterig system together with radio stations with detachable control panels like Kenwood TS-480, TS-2000 or ICOM IC-706 and others. You simply replace the cable between the control panel and the radio with the Remoterig system. You will get the same feeling and functionality as with the original setup.

Transmitter Interlocks

The transmit command is not initiated by a SCADA command.

The transmitting is usually initiated via Remoterig and an "on" command comes from the ICOM Transceiver at the HF site to control the on-site systems. This is in the form of a ground (0) during the period of a transmission. This "TX On" command does the following:

1. Inhibits operation of the Antenna Selector assigned to that Transceiver while transmitting
2. Inhibits operation of the 4 Square Control Unit assigned to that Transceiver while transmitting
3. Turns the linear Amp to TX that is assigned to that transceiver; subject to the pre-programmed inhibit switching on the Band Switching Interface Panel.

If the transceiver is operated directly from the HF site itself the "TX On" command also does 1-3 above.

Antenna Directivity Switching

The significant change in policy and design philosophy by QHUG has been the acceptance of much physically smaller antennas compared to the large wire antennas used at Quartz hill site where space was abundant.

By using smaller steerable antennas such as the single band 4 Square arrays there is a need for more remote control functions to steer the directivity of the array. These arrays are designed for receiving and transmitting up to 1kilo Watt of RF power.

The use of directivity switching using **4 Square Control Units** driving a **4 Square Phase Switch** for the 4 Square antennas is described here. There are 4 commands that are required that switch the main lobe of the antenna pattern to any one of four directions. These are typically clockwise around a compass:

Cardinal Point:	NW	NE	SE	SW
Bearing:	315^{o} T	45^{o} T	135^{o} T	225^{o} T

The **4 Square Control Unit** selects the antenna direction with a momentary pulse from either the push buttons on the Control Unit or by remote command from the SCADA system.(a momentary ground or "0" on the appropriate pin)

The **4 Square Array Phase Switch** provides an analogue indication of the balance power being absorbed by the balancing load in the phase switch. This is connected to the SCADA to provide this indication back at the base node.

The direction of the 4 Square arrays is controlled in the phase switcher that splits the RF to the four driven vertical elements. There are four different configurations of phase of these feeds to achieve the directivity. The type of phasing used in this design is centred on a hybrid 3dB coupler which is also known as a Collins Hybrid Coupler.

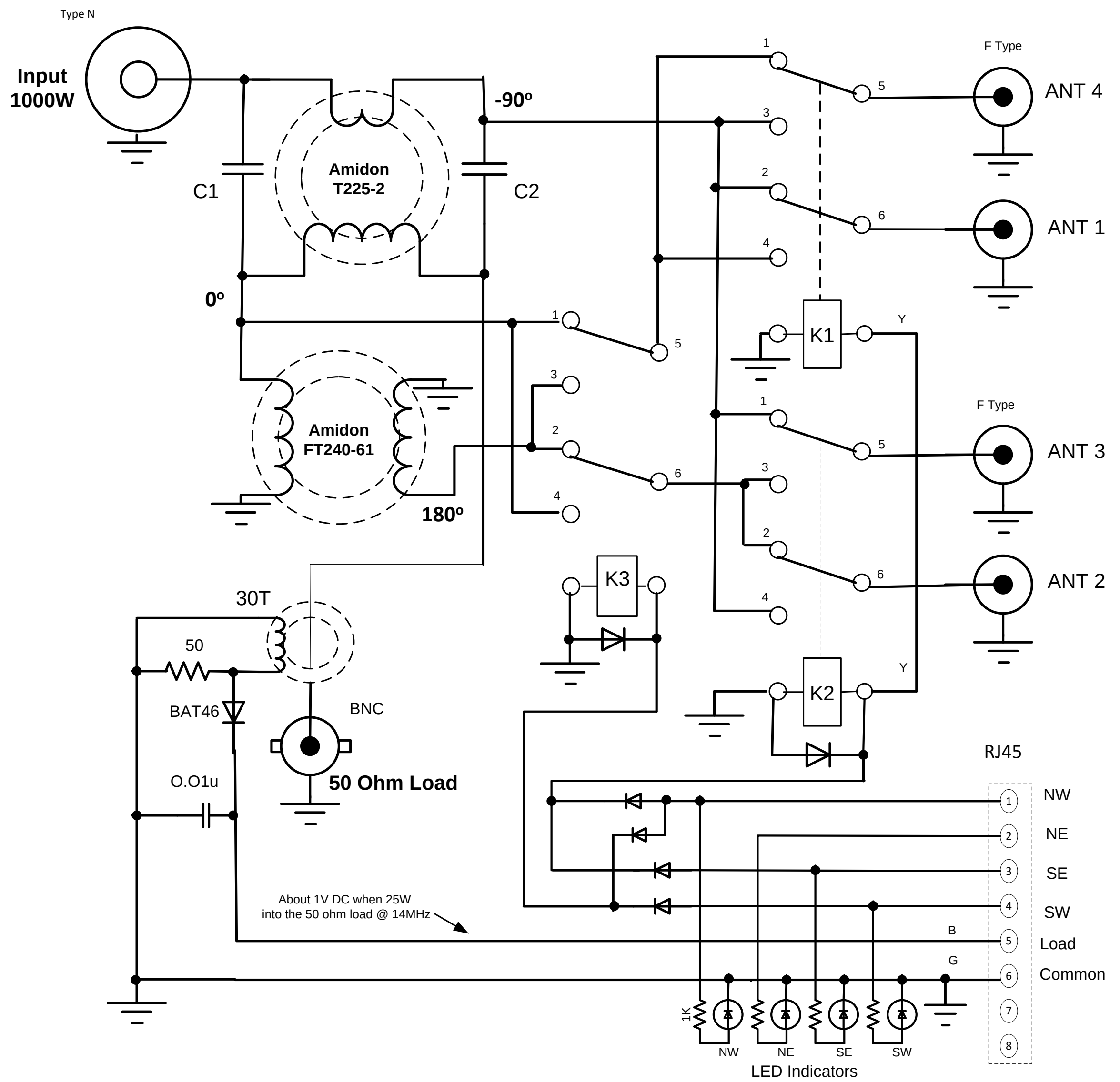
The design used here has been adapted from that published by TK5EP.

The directivity switching is achieved using two modules that are described below.

1. Hybrid coupler phase switcher
2. 4 Square Array Controller

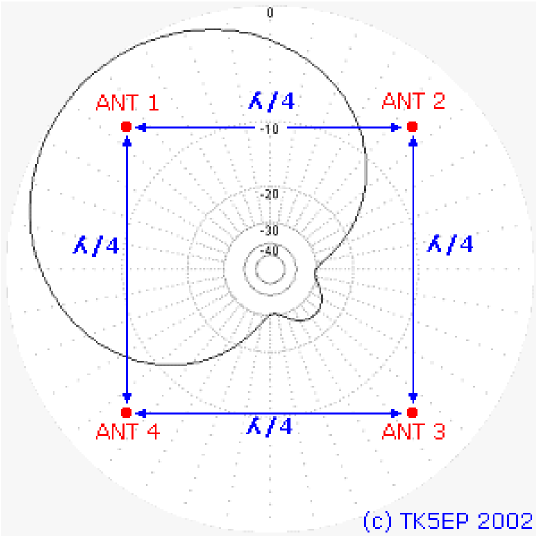
Hybrid Coupler and Phase Switcher

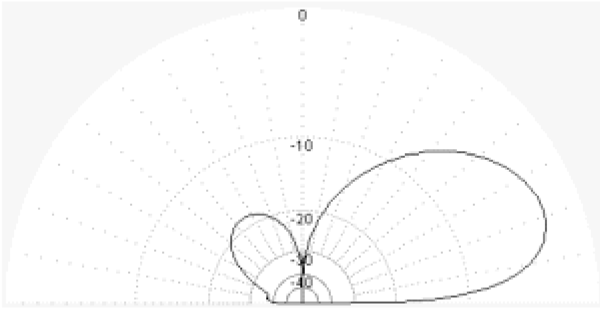
Drawing 13 Hybrid Coupler and 90º Phase Switcher



Directions, phasing and relay powering							
Direction	**K1**	**K2**	**K3**	**Ant 1**	**Ant 2**	**Ant 3**	**Ant 4**
NW	1	1	1	180°	-90°	0°	-90°
NE*	0	0	0	-90°	180°	-90°	0°
SE	1	1	0	0	-90°	180°	-90°
SW	0	0	1	-90°	0°	-90°	180°

Azimuth and position of antennas, system in NW position





Elevation pattern.

Winding the Transformers
T1 Hybrid Coupler
Toroid core Amidon T225-2
Bifilar wound twin insulated wire


Collins hybrid phasing transformers wound on T225-2 Core

T2 Wideband 180^o Phase shift Transformer
Toroid core Amidon FT 240-61
Bifilar wound twin insulated wire

T3 Load Power sensor
Torrid Core
Single winding of 30 turns evenly spaced.
About 500mm of thin insulated hookup wire

The hybrid coupler, if well built, will deliver equal voltages on the output ports as well as negligible voltage on the isolation port. The phase shift between the ports is shown in the table above.

The equal voltages on all ports is true only if the impedances of the loads on all ports are 50 Ohms. This is in practice will never be perfect, so the balance load will likely dissipate some power.

A 4 square array needs equals currents on each antenna to work properly. In practice, the antenna impedances are not perfectly equal, varying on each antenna due to mutual coupling as well as during beam direction change. Feeding the antennas through feed lines that are 1/4 wave long or an odd multiple of a 1/4 wave long, forces the antennas to have the same currents in them even though they do not have the same feed point impedance. That's called “current forcing”.

Feeding the antennas with 1/4 wave long feed lines is very important !

The phase switcher is designed to drive a four-antenna phased array.

With 4 antennas, arrays are mounted in a perfect square with 0.25 lambda side, the beam directions are along the diagonals.

The phasing lines are quarter wave of 75 Ohm coaxial cable. Use at least a cable with 0.76 velocity factor, otherwise with 0.66 factor the lines will be too short to run to the centre of the square (where the phasing box should be) with a quarter wave. Otherwise, you will have to cut the lines 3/4 lambda long.

CATV distribution coaxial cable with foam dielectric with F type connectors is the recommended cable for the 75 Ohm feeders between the phase switcher and the antenna elements.

Design Reference:

References worth a look on google:

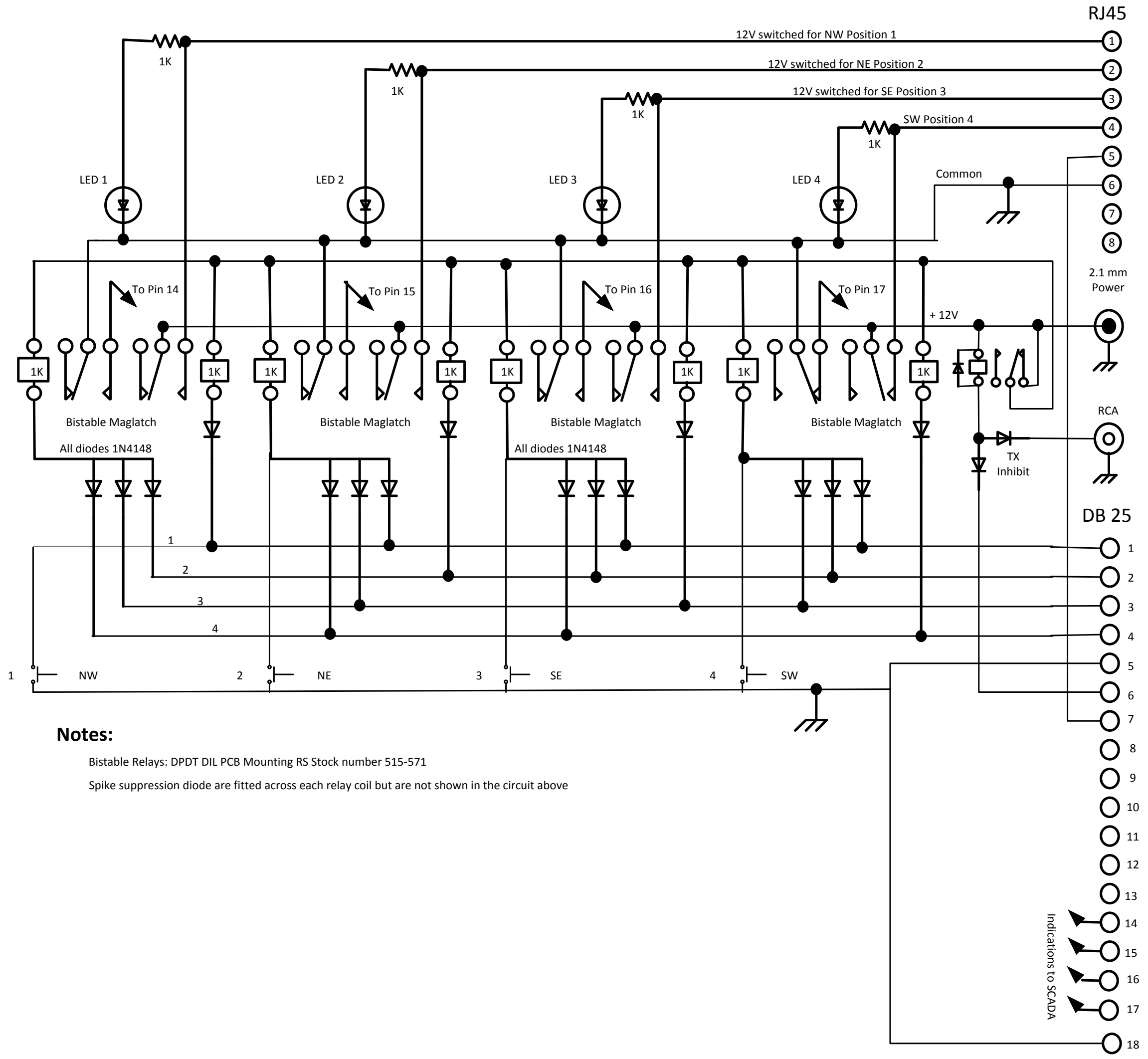
1. TK5EP’s 4 square vertical system
2. “DF6Qv 4SQ’s with 90 degrees couplers”
3. Chapter 11 ON4UN

Bill of Materials (BOM) –Hybrid Coupler Phase Switcher

Item	Description	Each	Approx Cost
1	T1 Made on Amidon T225-2 core	1	$20
2	T2 made on Amidon FT 240-61 core	1	$20
3	T3 Load Sensor L8 torroid	1	$2
4	Disc Ceramic HV Capacitors C1 and C2	2	$10
5	K1, k2, K3 DPDT Relay 10amp contacts 12v coil	3	$30
6	N Type SKT Chassis MTL (1 Input)	1	$9
7	F Type SKT Chassis MTL 4 outputs	4	$10
8	Type BNC 9.5mm MTL Load connector	1	$5
9	Splash proof enclosure 171x121x80	1	$27
10	Transformer Mount Plate: Polythene Sheet	1	$2
11	Solder tags	20	$5
12	3mm bolts and nuts	10	$5
13	D1 and D2 Spike suppression diodes 1N4007	2	$1
14	BAT 46 Schottky Diode – RF detector	1	$1
15	Resistor 51 Ohms ¼ Watt	1	
16	Capacitors 0.1uF 250V	5	$2
17	RJ 45 socket	1	$4
18	Veroboard 25mmx50mm	1	$3
19	Twin wire 1mm stranded copper conductor-1metre	2	$6
20	RF Hookup wires solid 1.5mm 1metre	1	$2
21	100watt 50 Ohm Load with BNC connector	1	$26
		Total:	**$190**

Four Square Array Controller

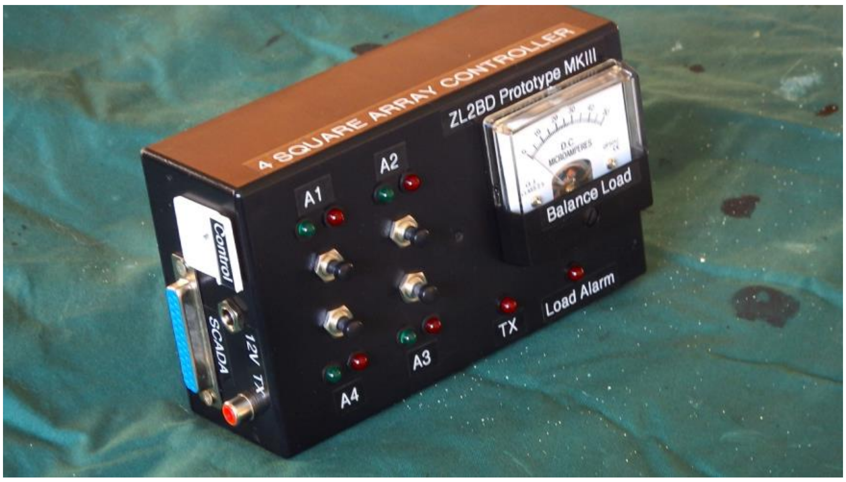
Drawing 14 Four Square Array Control Unit



Notes:

Bistable Relays: DPDT DIL PCB Mounting RS Stock number 515-571

Spike suppression diode are fitted across each relay coil but are not shown in the circuit above



Circuit Description

The controller described here is used where remote operation is intended. This design offers the following features:

- Antenna direction switching using 12 volts over low cost computer data cable and RJ45 connectors
- Input and outputs for SCADA on a DB25 connector.
- Momentary push-button selection of antenna direction either at the field end or the base station end.
- Memory of last selected Antenna direction is retained when power is removed from the control boxes at either the base station or the field end.
- Universal design approach so that identical control boxes can be used at each end of a SCADA system

If remote operation is not required then a simple 4 position rotary switch could be used for local selection of the antenna direction.

The unit operates on 12volts. It supplies power to the relays in the 4 Square Phase Switcher out at the antenna.

Bistable relays (Maglatch) are used, one for each antenna selection. For example when pushbutton A1 is depressed momentarily, bistable 1 (BS1) switches and applies 12v to output RJ45 pin 1. At the same depression BS2, BS3 & BS4 have a pulse applied to their coils to deselect them. Similarly when A2 is depressed momentarily, BS2 switches power to RJ45 Pin 2 and at the same time a pulse is applied to BS1, BS3, & BS4 to deselect them. A green LED across each output on the RJ45 indicates which output is active (with 12v on it).

Four green LEDs associated with each of the four switching functions are wired to inputs on the DB25 Pins 21,22,23, & 24. These can be used as indicators from the SCADA on the status of the bistables in the identical box at the other end of the SCADA link.

The relay contacts wired to the DB 25 pins 14,15,16, & 17 can be used to tell the SCADA the status of the bistables in this box.

When TX RCA input is earthed (or DB25 pin 6), power is cut from the the bistable relay coils so that antennas cannot be changed while transmitting.

The design presented here uses the analogue voltage on pin 7 of the DB25 to supply an A to D converter in the SCADA and supply a RF level indication back to the Base Node.

Relay-less controller option

An option to use a solid state design with no relays for the controller was considered and rejected as relays are believed to be more robust in the high RF environment that is likely near the transmitting antenna and less likely prone to unpredicable switching especially if power is interrupted at either end of the system. The cost and complexity of either the solid state or the relay options is about the same.

Bill of Materials (BOM) -4 Square Array Controller

Item	Description	Ea	Approx Cost
1	Bistable Relays DPDT. (BS1, BS2, BS3 & BS4)	4	$28
2	Change over relay DPDT (Rel 1 and Rel 2)	2	$20
3	Push button Switch SPST -N/O	4	$8
4	RJ45 connector panel socket	1	$5
5	DB25 conector female panel socket	1	$3
6	1N914 Diodes	26	$2
7	LEDs Red 5mm	6	$2
8	LEDs Green 5mm	4	$1
9	555 timer IC	1	$1
10	741 op amp	1	$2
11	50 microamp M/C panel Meter	1	$22
12	Jiffy Box ABS Plastic 95 x150 x50	1	$6
13	Miscellaneous minor components, nuts and bolts	several	$5
14	RCA socket	1	2.50
15	2.1mm power plug (12v)	1	2.50
		Total:	**$110**

Note: Item 1 used an alternative model of low cost bistable relays from RS Components at a cost of about $7each. i.e. $28 total. The more readily available bi-stable relays that are larger and can be sourced from Jaycar are $15 ea

Lightning Protection

Lightning protection systems - What they do and don't do

A lightning protection system's only purpose is to **ensure safety to a building and its occupants if lightning happens to hit it directly**, a task accomplished by providing a good, safe path to ground for the lightning to follow.

Contrary to the myths, lightning protection systems:

- **Don't** attract lightning
- **Don't** and **cannot** dissipate or prevent lightning by 'draining' a storm of its charge
- Most **don't** offer surge protection for sensitive electronics
- **Do** offer fire protection and structural damage protection by preventing a hot, explosive lightning channel from passing through building materials

Lightning dissipation / elimination myths

Products called 'lightning elimination' or 'lightning dissipation' devices have arisen as a result of two myths:

1. a thunderstorm's charge can be drained or otherwise affected by objects on the ground.
2. cloud-to-ground lightning discharges begin from the ground.

Products, that are still being sold today, claim to be able to prevent a direct lightning strike to any object on which they are installed. – This is nonsense-

Cloud-to-ground lightning strokes initiate high in thunderstorms, many kilometres above the surface where ground objects have no effect. Even after initiation of the discharge, the downward-moving stepped leader is 'blind' to objects on the ground until it is very close to the ground, within 20 -30 metres! At that distance, lightning will strike within the very small area it is already descending in, regardless of any devices nearby that claim to divert or prevent the strike.

Despite the evidence, various devices continue to be sold, installed and promoted presumably by the same charlatans that sell copper bangles to ward off evil spirits .

Lightning protection facts

- Rods and protection systems don't attract lightning, nor do they influence where lightning will strike.
- Rods or protection systems do not and cannot prevent lightning, nor can they 'discharge' thunderstorms.
- Lightning protection systems (including placement of rods, cables, and groundings) are custom-designed for individual situations and require complex engineering to function properly.

Components of a lightning protection system

Lightning rods or 'air terminals' are only a small part of a complete lightning protection system. In fact, the rods may play the least important role in a system installation if they do anything at all. A lightning protection system is composed of three main components:

1. **Rods or 'Air Terminals'** - The small, vertical protrusions designed to act as the 'terminal' for a lightning discharge. Rods can be found in different shapes, sizes and designs. Most are topped with a tall, pointed needle or a smooth, polished sphere. The funtionality of different types of lightning rods, and even the neccessity of rods altogether, are subjects of many scientific debates.

2. **Conductor Cables** - Heavy cables that carry lightning current from the rods to the ground. Cables are run along the tops and around the edges of roofs, then down one or more corners of a

building to the ground rod(s).

3. **Ground Rods -** Long, thick, heavy rods buried deep into the earth around a protected structure. The conductor cables are connected to these rods to complete a safe path for a lightning discharge around a structure.

The conductor cables and ground rods are the most important components of a lightning protection system, accomplishing the main objective of diverting lightning current safely past a structure. The 'lightning rods' themselves, that is, the pointy vertically-oriented terminals along the edges of roofs, do not play much of a role in the functionality of the system. A full protection setup, given good cable coverage and good grounding, would still work sufficiently without the air terminals.

For the Remote HF Station then, no lightning rods to “attract” are proposed.

Given that the primary objective purpose of lightning protection is to: **ensure safety to a building and its occupants if lightning happens to hit it directly**, this is best achcieved by making sure all parts of the installation remains at the same electric potential in the event of such a hit.

Installation guide:

- Metal bonding to a common earth point is proposed at the point all cables enter the equipment hut. No cables entering the hut should be allowed by-pass this requirement.
- All Coax cables and sheilds or control cables should be connected to a driven earth at the base of metal antenna support poles or pipes. This is in addition to the earthing of them at the hut entry.
- During any lightning storms personnel should leave the site with haste.