The FULL Story of the South Coast Microwave Beacon Complex

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In early May 2002 operation of the largest UK single site amateur microwave beacon installation commenced from a hilltop in rural Dorset. This is the story of how it got there and what has been happening since.

This article is offered as encouragement to other Repeater Groups and individuals to add to the UK microwave beacon resource

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Background to the microwave beacons

In 1986 John G8MCP and Nick G8MCQ applied for a licence for a 10GHz wideband beacon for the Bournemouth area, and the callsign GB3SCX (South Coast X-Band) was issued but unfortunately was never built. In 1992 John, now G0API, and Andy, G4JNT, decided to resurrect the proposal but, instead, to build the beacon to assist microwave operators with the then up-and-coming narrowband mode of operation. A beacon was built, tested and installed at the site of the 2 metre and 70cm repeaters GB3SC and GB3SZ located on a tower block in Bournemouth, 34m above sea level. The RF chain consisted of modules designed by G3WDG and G4DDK based around a 108MHz crystal oscillator followed by frequency multipliers and filtering to a final output at 10368MHz. One of G3WDG's then newly-designed Power Amplifier modules supplied 180mW to a homebrewed 16 slot waveguide antenna giving a radiated power of a little over 1 Watt – more than enough to assist microwave operators on portable sites in the south of the country. Some of the best reported reception was from G3FYX and G3JMY who regularly received it in Bristol via tropo and rain scatter modes.

But the site was not ideal and a higher location would be far preferable. After a year or so of operation, the offer of a site at 200m above sea level on the Purbeck Hills overlooking Swanage became available. Propagation in most directions would be far better, and access for maintenance made slightly easier. A dedicated luffable mast was part of a facility managed by Bren Gordon, G4GHP, for mobile radio and hospital communications. There was plenty of room on the tower for GB3SCX, and it was hinted that space could be made available for more beacons on other bands. A temperature controlled underground bunker, originally built for TRE Worth Matravers for Radar development during WW2, housed all the equipment at the site, and also the local Band 2 FM radio station 2CR. The temperature control gave the very important advantage of a stable environment for the microwave sources. GB3SCX was fitted into the equipment rack, the head unit mounted and connected to its feeder and the beacon became operational from the site in 1994, helping many microwavers to set up frequency and beam headings.

After getting a few hints about more space being available on the mast, we then had the completely mad idea during a Microwave Round Table meeting at the Flight Refuelling Amateur Radio Society (FRARS) of building and installing beacons for all the microwave bands - the long process of applying for licences started immediately, with the callsigns requested shown in Table 1.

Licences were eventually received and the hardware-build process started. By this time several members of FRARS, including Julian G3YGF and Carl G6NLC had been involved in the design and construction of what became the second 10GHz EME capable station in the UK. The experience led to the nucleus forming of the group who went on to build the next phase of the beacon project. In order to reflect the beacon aspect, the group became known as the South Coast Repeater and Beacon Group (SCRBG).

We looked for assistance to build these, and Chris G8BKE took on the task of supplying the 24GHz hardware, while Mike, G0JMI offered to build for 2.3 and 3.4GHz. Eventually all were made operational, and for a short time we actually had four microwave beacons running from the Purbeck site. Then disaster struck – the site owner had negotiated a deal with a mobile phone company and the beacons had to go. We needed a new site quickly!

The Bell Hill Site

The choice of replacement site was influenced by several factors. Apart from the absolute necessity of a location with a commanding view over the surrounding landscape, the site needed to have an adequate mains electricity supply and be affordable. Bell Hill is located on a high ridge next to Bulbarrow, which is 278 metres above sea level and one of the highest points in Dorset.

G0API had noticed a four section Versatower supporting a pair of folded VHF dipoles and had assumed they were in use for PMR. A phone call to the farmer who owns the land revealed that the mast had been used by a local veterinary practice and had fallen into disuse after the advent of cell phones - the irony of that did not go unnoticed - and led to an offer to take over management of the mast and the somewhat dilapidated, but solidly built equipment block house underneath (see photo). A promise of financial support was generously made by the committee of FRARS, and the decision to fund the balance taken by the principal group members - a step into the unknown!

An initial site evaluation in September 2001 revealed the extent of work required before the real business of beacon installations could commence. The door of the equipment hut had become detached some years before and the hut's main function had become that of an animal shelter.

Notwithstanding the average round trip distance to the beacon site of 150km and that the external work would need to occur throughout the depths of winter, the first site rental cheque was handed over and work commenced.

Winch and Tower Restoration

Operation of masts on exposed hilltops should not be undertaken without adequate guying – in this case three sets of four guys had been fitted following an incident where the unguyed top section had folded through 90 degrees after the 1987 hurricane. The metalwork of the mast looked to be in reasonable condition. The galvanised steel luffing and haul wire ropes were in a rusty condition and the tie-bars on one of the winches had almost rusted through, so it was with some trepidation that the first attempt to lower the mast was made.

The real trouble started when we began to lower the mast and the haul rope started to "twang", followed shortly after by a pistol shot noise and a shower of rusty rope fragments descended. "Oh bother" was a close approximation to the collective exclamation. Fortunately the urge to climb the extended mast had been fully resisted and the only damage apart from the haul rope was to the several wooden spars previously inserted through the lattice to prevent the mast from telescoping unintentionally – wood is easily replaced, hands and feet take a little longer… The only solution was to install a new haul rope *in-situ*.

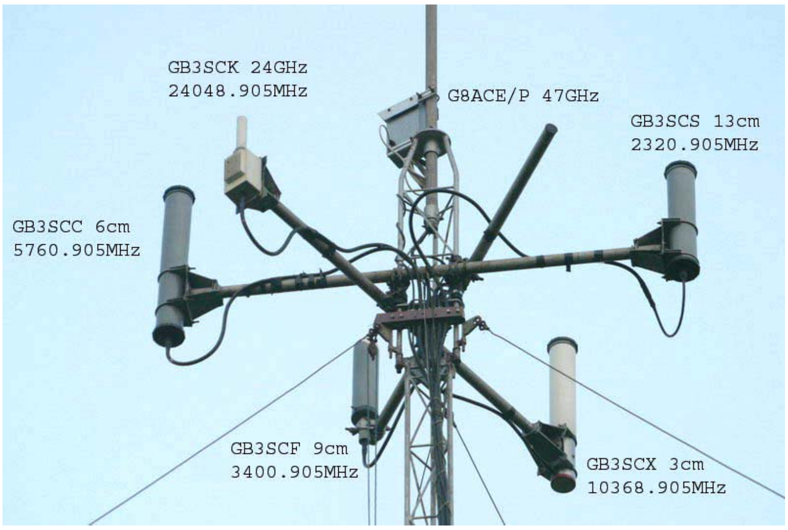
It rained solidly for the four hours that it took to rig a replacement haul rope. The sight of G3YGF applying saddle clamps whilst roped to a ladder at 7m above ground in a force five and driving rain was unforgettable! With the haul now working the mast was fully telescoped and luffed. The 12 sets of 6mm guys and bottle screws were then removed for a soak in diesel for a week or two…

The winches were fully stripped, damaged items replaced and all generously lubricated with a good quality moisture repellent of the type used to protect Motocross chain drives – this stuff sticks and provided you protect it from direct rain with plastic sheet, will remain for many months. On several subsequent site visits, all external mast surfaces were rust proofed and a coat of grey Hammerite applied. For a mere £100 a new 8mm luffing rope was acquired and a pair of new 6mm stainless steel ropes with hydraulically crimped thimbles followed. Our mast was working but very empty.

Mast-Top Design

Facilities on elevated sites such as this at 270 metres need to be conservatively designed if they are to survive the vagaries of UK weather. We were fortunate in already having the 25 metre, four section Versatower on site. The specifications indicated that it was capable of unguyed use at full height with a head loading of 60kg, in wind speeds up to 120 mph. Having seen the results of the 1987 Hurricane on the previous top section of this mast we decided that although it now had four sets of guys, to use it only partially extended at a height of 14m to ensure its survival. Extra height would be of no benefit as it cleared all local obstacles and would just increase feeder losses. By careful design of mounting hardware the 60kg head load limit could just about be met - the triple guy sets do contribute considerably to this figure - but at the reduced mast extension was considered reasonable. Each 75 x 75 x 6mm steel angle section ground anchor point was extracted, cleaned and replaced.

The structure was designed to site all antennas close together with minimal interaction by mounting them on three 2 metre sections of aluminium scaffold pole clamped across the faces of the triangular mast. This involved using six galvanised scaffold clamps, the connections to the head unit being fitted with heavy duty UV-proof plastic sleeve inserts, lathe bored and axially split for a tightly clamped fit.



Beacon Housing

Each head unit was enclosed within a vertically mounted radome made from u-PVC drain pipe. The material was investigated for RF loss by the microwave cooker technique – when it did not get warm after 3 minutes at 600W it was considered to be OK. White or grey pigmentation seems to be the best – avoid darker colours as they not only absorb sunlight more readily, they also tend to be carbon loaded and therefore RF-lossy.

The material is relatively cheap, can be solvent bonded and suitable end caps are available with screw lids that include effective rubber seals. 4mm diameter holes were drilled through the base of each housing to allow condensation to escape. It is good practice to coat all exposed items with a good quality silicone based conformal coating; if cured with a hair dryer or similar heat source, this will ensure any surface moisture is excluded and long term corrosion protection is ensured.

The 2 Watt PA in the 10GHz housing required heatsinking to dissipate the 15 Watts of heat. The solution adopted was to use a 300mm length of heavy wall aluminium tube protruding below the radome and to interface the PA with the inner wall of the aluminium by machining a sector-shaped aluminium block. This was made long enough to accommodate the PA and x 4 multiplier combination. The sector was hand-lapped to be a very close profile fit to the tube by the use of coarse grade valve lapping compound. The joint was coated with a thin film of void-filling heatsink compound – resulting in good thermal transfer to the outside face of the tube, and giving a large radiating surface area. Monitoring the heat rise over several hours confirmed the surface temperature stayed at an acceptable level.

Mounting

The vertical radomes were mounted on the two metre scaffold tube horizontal spars, using standard exhaust C clamps and 3mm thick aluminium sheet. The sheet in this instance was salvaged from scrap roadside signs donated to the project. The half-hard alloy material has excellent corrosion resistance and provides good load carrying capabilities for its low weight; the light-reflective markings are not mandatory. All metal surfaces were coated with an aluminium based paint and screw threads coated in durable moisture repellent gunge.

All cables enter the housings from below to prevent water ingress. Good quality silver plated N type bulkhead sockets are worth the expense, but even these and the mating plugs should be carefully protected by wrapping with self-amalgamating rubber tape, then with PVC tape to ward off UV degradation.

Feeder Cables and supports

Feeder cables were all LDF-450 Heliax. This is not the most flexible cable to work with, particularly when in a bundle of five, but provided that the minimum bend radius is adhered to it has proved to be durable in the long term when fully exposed to the elements. The outer plastic jacket is particularly good at resisting the shotblasting effects of airborne particles such as sand grains, presumably from the surrounding fields during the ploughing season. Multiple coats of enamel paint oversprayed with clear lacquer applied to the heads have been found to disappear after 2 years exposure in these conditions.

With the mast at operating height, the umbilical consisting of five coaxial feeders and auxiliary cables are required to hang vertically for 14m from the head section. This contravenes the cable installation specification and as we did not have any of the special Heliax fitted with integral steel wire catenary, we designed an alternative mounting. The weight of the cables is carried by a "revolver breech block" made of Tufnol half way up the cable run. Each cable is gripped by a jubilee clip and rubber sleeve which is fitted in its individual slot in the block. If the cables were simply gripped together the cableform would become too stiff to bend, causing difficulties when telescoping the mast.

The block is supported from a rope and pulley wheel on the top of the first tower section and can be tensioned from the ground – this carries about half the weight of the cable. Rubber coated aluminium hoops were jubilee-clipped to the upper stages of the mast to allow the cables to be raised and at the same time prevent them from swinging in the wind.

At the top, the cables are gripped by a purpose-designed multiple pipe grip fashioned from 25mm thick silicone rubber sheet clamped between Tufnol blocks with holes drilled for each feeder.

A short section of flexible plastic pipe at the base of the mast is used to duct the cables through the outer wall of the equipment hut. Bunging up all holes and entry points into the building prevented animals from getting in, and had the added advantage of reducing heat loss – you'd be amazed to see the damage caused by mice.

All LDF-450 runs were terminated by standard N-type plugs of the sort used on URM67 flexible cables. In order to preserve the characteristic impedance the centre pin transition adapter design of G3YGF was used [1]. The fully soldered and terminated cable runs were tested for loss at 10GHz using a network analyser, which revealed that one particular cable had a much greater loss than expected. This turned out to be due to the way the heliax outer had been soldered to the clamping nut – we had created an effective quarter wavelength coaxial sleeve choke that acted as a frequency selective 12dB suck-out at the test frequency.

At Ground Level

The equipment is housed in the original building which is of concrete block construction with a 150mm thick solid slab roof. Several coats of exterior water repellent paint were applied and the interior walls painted. Condensation is a big problem in a hut such as this and was solved by covering all internal walls and the metal door with polystyrene insulation to prevent the moist air from reaching the cold surfaces and reduce heat loss.

We installed comprehensive monitoring of external and individual equipment item temperatures and have been pleased with the relatively small temperature changes. Heat from the rack-mounted power supplies and amplifier modules maintains the internal temperature at approximately 10C above external but with the seasonal variations reduced somewhat.

Whilst the mains supply has an earth connection via its armouring, this was far from satisfactory. A large earth radial system and several ground rods were installed and a lightning spike was fitted to the highest point of the mast and fed back to the ground connection via its own cable. All RF feeders, the earth radials and the 19” rack are firmly bonded together inside the hut. The idea here is to force the complete system to jump together, maintaining a zero potential with respect to one-another in the event of a nearby lightning strike. Additional protection was added later by way of Varistors across the incoming supply lines, following the demise of several capacitors in the SMPSU after a nearby lightning strike.

Antenna Systems

Although established designs were used for each band, some effort was put in with an antenna test range to establish that they performed as intended – in some cases this proved not to be the case…

Any antenna test range requires careful consideration in order to avoid misleading results. You need to be in the far field, but not much beyond otherwise unreasonably high masts are needed to prevent ground reflections from affecting the measurements (Fresnel zone clearance).

The far field distance is given by:

$$d_{min} = 2.D^2/\lambda$$

where d = measurement distance
and D = largest antenna dimension

We managed to do our tests by obtaining permission from a neighbour of G0API to allow the temporary siting of the G3YGF Landrover, complete with scaffold pole supporting the Versatower top section, and all beacon radomes on her drive, see Photo [5] This placed the system in the far field and a variety of waveguide horns were used as test antennas on a large tripod, built out of scaffold poles and rope.

Signal sources consisted of signal generators and the actual beacons. By monitoring the signal received on the test antennas with a spectrum analyser, and knowing the path loss and insertion loss of the feeders, the gain of each of the beacon antennas could be determined. By feeding the received signal level into a paper chart plotter, the complete beacon head array could be rotated and a polar plot made. This helped to confirm the lack of interaction between the various structures on the head, which to our relief indicated that we had not managed to introduce too many signal nulls in the otherwise omni-directional characteristics of the individual antennas.

Similar tests were conducted with each individual antenna and it was during these tests that it was found that the all-important narrow horizontal radiation angle of the 2.3 and 3.4GHz Alford Slots was considerably wider than predicted, with resultant loss of gain. Investigations followed and it was found that in scaling design data from the original G3JVL notes for 1.3GHz, someone had forgotten that the standard copper water pipe he had used needed its circumference to be reduced in order to obtain the correct slot/diameter relationship. New radiating elements were slot-milled and the original data verified to be correct! It is worth noting that the 3.4GHz version was still not quite optimised and that measurements with a network analyser showed that some adjustment was needed to obtain a good match

Power Supplies

Our first site visit showed that the power came from a box in the back garden of a house at the bottom of the hill 1km away. This was turned on and we measured 245V off-load back at the hut. The supply came through a length of buried armoured cable with a pair of $1.5mm^2$ conductors so we knew the amount of mains power would be limited. With a total go-and-return length of 2 kilometres, the resistance of the feeder was 23 ohms. As an experiment we plugged in a 2.5kW kettle, whereupon mains voltage dropped to around 120V – it was operating into a matched load!

At that stage some of the existing beacons needed an external 12V DC supply, others had their own internal PSUs. It would only be possible to take a couple of hundred watts before mains voltage dropped to an unusable level, so ideally we would need a switch mode PSU capable of operating over a wide range of input voltage and then try to run all the beacons off it.

A 250 Watt Uninterruptible Power Supply (UPS) that included an internal 24 Amp-hour 12 Volt battery was available. Testing this by using a variac to adjust the input voltage showed that the unit functioned properly down to 210 Volts while delivering 15 Amps at 12V. This looked as if it could form the basis of the PSU for the whole complex, giving the 12V supplies from its battery and conditioned 240 VAC from the main UPS output. We would also have the advantage of battery backup to keep the beacons operating if we needed to disconnect the mains for a short period.

Remote Control and Monitoring

With the power supplies sorted out, it was now time to consider how the remote facility would be managed. The site was at least 30km from the group's members houses (96km from G4JNT and G3YGF) so manned turn-off would be impractical. The previous site on the Purbecks had already been approved for remote turn-off using DTMF signalling over a radio link, and this was also requested when the licensing application for a change of site was sent in. In case of real emergencies, we identified a local farmer with an amateur licence, Geoff G7RMG, who could get to the site within the statutory 20 minutes.

The remote control installed on the Purbecks had comprised only of a 430MHz FM receiver and simple hardware decoder. This was a bit restrictive in that after a remote turn-off command has been issued, the only feedback that the command had been successfully received was that the associated beacon transmission ceased. Also, the decoder in use could only control up to three circuits and would not do for the new beacon set, so a completely new controller system was designed. This was built around a TF-7 70cm transceiver module [2], a DTMF decoder, and a PIC microcontroller; it can control up to eight relays with isolated outputs for switching, giving some spare capacity for future expansion. Having a bi-directional UHF control link meant that not only could the on-off commands be verified immediately they were issued, but it would also be possible to monitor various operating parameters such as voltage, current and cabin temperature.

Command Security and Telemetry

Control of a remote facility such as this using simple DTMF tone signalling on an open amateur band could lead to security issues, with hackers trying to upset the operation. So, to combat this possibility a secure access scheme was introduced. To access the command system, an operator has to enter a four digit PIN, then check to see if the system has acknowledged before any commands will be accepted. To prevent hackers decoding the access code by listening and decoding the transmitted tones, the PIN is changed for each successive access on a pseudo-random basis, and operators have to look up the next valid set of digits from a list for each new attempt. As a final touch, three separate lists of PINs are maintained so that several authorised shutdown operators can each have independent access to the control system without having to consult each other to find where on the list they are at any one time.

Within the beacon control system, another PIC processor with a multi-channel analogue to digital converter monitors AC voltage and current, DC supply voltage and shack temperature as well as several digital status lines, for example a door entry switch. By sending the appropriate DTMF code on the command link, the values of all these parameters can be returned in a CW message and the state of critical hut parameters read at the remote site. Mains voltage and current are interfaced to the logic circuitry via an isolation unit containing two transformers for current and voltage monitoring.

Automatic power protection.

Recently, after the PSU was damaged by lightning induced transients and the battery discharged to such an extent it was destroyed, a protection scheme was added. The telemetry unit was modified to issue commands if the mains voltage or DC supply falls below a certain threshold. If either of these trip, the beacons are automatically switched into a low power standby mode where oscillators are kept running, but head units and PAs are turned off, lowering current consumption to 3A which the battery should be able to supply for several hours. Full operation resumes as soon as voltage levels are restored.

In case of long duration outages a hardware voltage monitor cuts the supply to everything when battery voltage falls to 10 volts in order to save the battery itself. Again, this automatically resets when power is restored.

Beacon RF Hardware

A block diagram of the complete set-up is shown in Figure [1] All the RF units have undergone several modifications, and in some cases a complete rebuild, since their first outing on the Purbeck site. Frequencies and EIRPs of each are given in Table 1.

Table 1

Frequency	Callsign	Output EIRP	Notes	
2320.905MHz	GB3SCS	3 Watts		
3400.905MHz	GB3SCF	6 Watts	GPS Locked, RTTY Data	
5760.905MHz	GB3SCC	10 Watts		
10368.905MHz	GB3SCX	18 Watts	GPS Locked, RTTY Data	
24048.905 MHz	GB3SCK	5 watts		

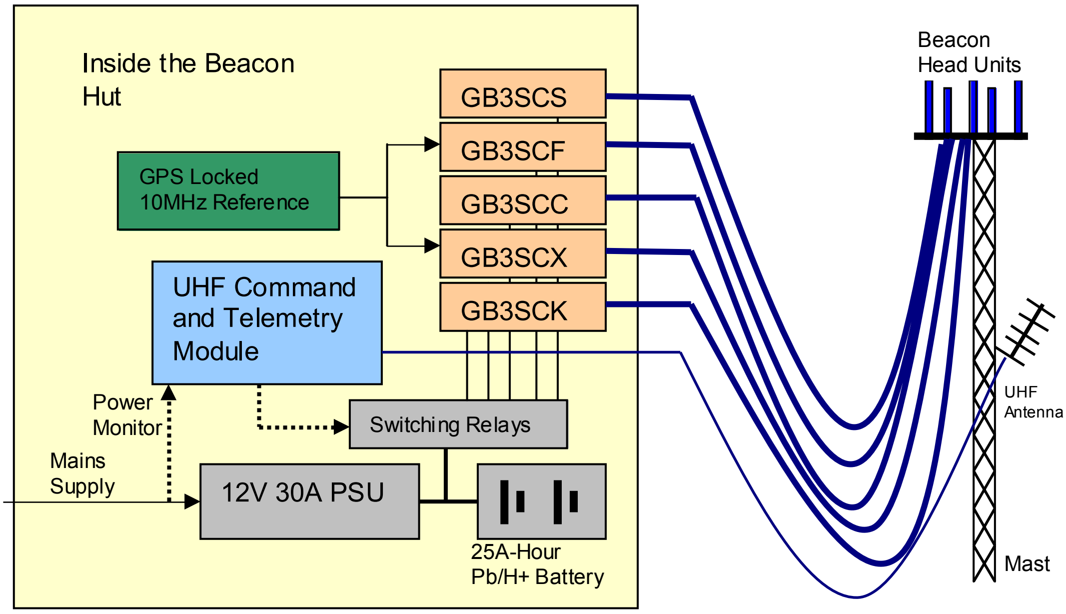


Figure 1 Block Diagram of the Beacon Complex

GB3SCS 2320.905 MHz

The beacon starts off with a 96.7MHz crystal in a Butler oscillator followed by a X4 multiplier to 387MHz in a single module. A clip-on crystal heater reduces oscillator drift as the external temperature varies. The output is fed to a modified DDK004 module which further multiplies the signal by X6 to give the final output at 2.3GHz

The output from the DDK004 passes to a cascaded pair of RF2126 devices which generate 1 Watt of RF, then via a two stage comb filter to the output. At the end of the 15 metres of feeder it results in about 0.8W at the antenna which is a two electrical-wavelength-long Alford slot with an estimated gain of 6dBi

On-off keying is generated by switching the power to the final multiplier stage in the DDK004 with a PNP transistor. After some experimentation with keying earlier multiplier stages, it was found that if these were switched, the change in loading tended to get fed back to the oscillator and cause the keying to chirp. The message data is generated with a G0IAY/G4JNT PIC based keyer module which allows CW messages of different speeds as well as programmable pause lengths to be embedded within the single transmission.

GBSSCF 3400.90500000 MHz

This beacon started life in a very embryonic low power form on the Purbeck site, but only lived there for a few weeks. On moving to the present site is was completely rebuilt by Chris G8BKE. The line-up consists of an early version of the DDK009 module, starting with the now ubiquitous Butler oscillator at 94.47 MHz and followed by several multiplication stages giving X36 in total. Initially it used frequency shift keying for the CW message.

The output from this feeds a PA consisting of an Ionica module with the final devices removed and the output taken from the penultimate, driver, stage. Delivering a little over 1.5 Watts when saturated, at the end of the run of coax up the mast, 0.8 Watts feeds to the Alford slot antenna.

GB3SCF is the second unit of the complex to employ frequency locking to a GPS derived 10MHz reference. The same scheme as for GB3SCX was chosen, using a DDS 'in reverse' clocked by the VCXO to generate a signal at 10MHz which is phase locked to the reference using an NE612 mixer plus op-amp filter. The DDK009 module was modified to accept an external 94MHz input.

For this beacon, the AD9852 DDS chip with its 48 bit phase accumulator ensures the programmed mark frequency is just 40µHz low. An RTTY message was added to the normal beacon ident, with the PIC controlling the DDS containing all the CW and RTTY generation code in one piece of software. RTTY shift for this beacon was set to the standard 170Hz as rain scatter and other bandwidth widening phenomena are lower on the 3.4GHz band than they are at 10GHz

In the interest of conformity with all the other beacons on site, the ident was changed to on-off keying rather than FSK, necessitating the usual modifications to switch power to several driver stages within the DDK009 module.

GB3SCC 5760.905 MHz

The beacon hardware for this unit was provided by Neil Underwood, G4LDR and consists of a DB6NT 5.76GHz source module to generate the RF at a low level. Starting off with a 120MHz crystal this is progressively multiplied by 48 to give a filtered output at 5.76GHz at a level of a few milliwatts. The module was again adapted for on/off keying by switching the final multiplier stages; a G0IAY/G4JNT keyer module generates the CW message.

GB3SCC is the lowest frequency beacon of the complex to have any hardware (other than the antenna) at the head. As the feeder loss at 5.7GHz would result in hard earned power being lost, the PA module, which was a surplus 1W unit supplied by G4BRK, was mounted at the head unit and 12V DC power sent to it up the coax. Bias Tees had to be built in at base and head unit to separate the RF and power supplies.

The antenna is an 8+8 slotted waveguide with approximately 10dBi gain.

Bench testing of the PA suggested that with continuous operation it may run excessively hot in the summer months, so we initially ran the beacon on a switched basis. The keyer module allows a transmitter control function as well as keying the carrier, so this was used to switch power to the head unit on a 45 seconds on, 45 seconds off, cycle. Several users complained that this was confusing and as a compromise the off period was later reduced to 20 seconds. Then, after the promise that a replacement 5.7GHz PA would be forthcoming if the original got overcooked, the beacon was switched to continuous operation, and at the time of writing has survived its first year of hot summer weather.

A clip-on crystal heater keeps the final output within a few kHz of its nominal frequency - it does drift a few kHz over temperature. At some point this unit will also be converted to a DDS based GPS locked frequency source.

GB3SCX 10368.9050068 MHz

Initially this consisted of a DDK004 module with frequency shift keying, (later modified for on-off keying). The module contains a crystal oscillator at 108MHz, then progressive multiplication to give an output of a few milliwatts of 2556MHz which is combined with 12V DC power and fed up the coax to the head unit. There a WDG001 module multiplies this to the final output frequency of 10368.905MHz. Initially this was followed by a WDG006 PA module using an MGF1802 GaAs FET delivering around 200mW, but that proved unreliable over the years. After it had failed a second time, the entire head unit was rebuilt using a 2 Watt PA donated by Bren G4GHP. A block diagram of GB3SCX can be seen in Figure [2].

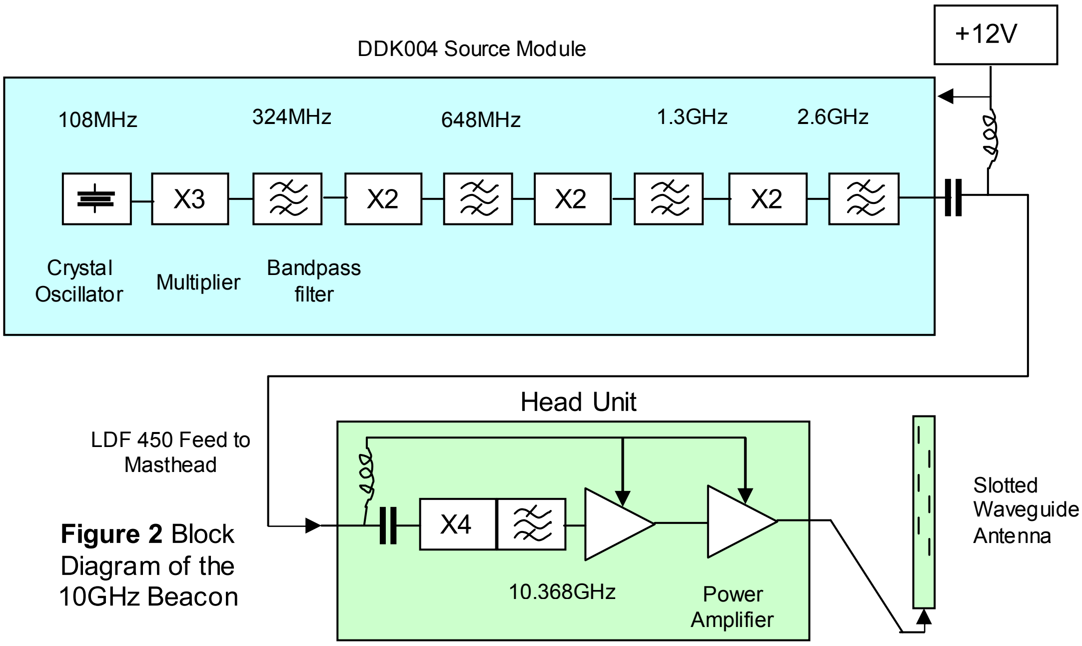


Figure 2 Block Diagram of the 10GHz Beacon

The antenna is a 7+7 slotted waveguide giving around 10dBi gain.

Even with a clip on crystal heater the free running Butler oscillator in the DDK004 gave poor frequency stability when exposed to the temperature variations of the Bell Hill equipment cabin. This experiences a greater excursion than the temperature controlled bunker on the old Purbeck site, so the source was replaced with one locked to a 10MHz OCXO (later GPS controlled).

A separate crystal oscillator is operated as a Voltage Controlled Oscillator (VCXO) delivering an output at 108MHz. This goes two ways – one output feeds the DDK004 to generate the final RF signal. The other goes to form the clock of an AD9851 Direct Digital Synthesizer. The output frequency from this chip is set to give 10MHz when clocked with exactly the right frequency to give 10368.905MHz after multiplication. The resulting 10MHz output from the DDS is compared in an NE612 mixer IC with the master reference input, and after amplification and filtering of the error signal in an op-amp, is used to control the VCXO frequency. Hence the VCXO is phase locked to the 10MHz reference at whatever fine-tuned frequency the DDS is set for.

The 200Hz wide PLL bandwidth proved wide enough to allow Frequency Shift Keyed RTTY to be put on to the final transmission. The PIC controlling the DDS chip was used to programme the device in real-time with two frequencies corresponding to mark and space of the RTTY with a shift of 850Hz, this being the widest available in standard RTTY decoding software. The Keyer software was modified to add an RTTY message, and the resulting data fed to the PIC controlling the DDS. A speed of 50 baud was selected, in common with most amateur RTTY use at VHF.

The 32 bit frequency setting resolution of the AD9851 DDS means that the programmed mark / carrier frequency of GB3SCX is actually 6.85Hz high at 10368.90500685Hz.

GB3SCK 24048.905 MHz

A decision was made early on, that if it was worthwhile having a 24GHz beacon then it would also be useful to have it as a stable reference source. Signals are difficult enough to find on the band without having to search across the frequency band. The beacon frequency was thus to be locked to an ovened 5MHz frequency standard. The design finally crystallised when a 12GHz "brick" with 96 MHz reference input was kindly donated to the project.

Initially the task of generating the 95.4321627MHz reference frequency for the brick was to have been by a Pye HS400 source but a neater and more compact solution using the WA6CGR synthesizer was adopted [4]. Final frequency trim in the order of tens of Hz is performed using the slight adjustment available on the ovened reference - the only part eventually used from the HS400. At first the scheme was to use a VCXO with a crystal at 96MHz as part of the loop, but this proved unreliable as lock couldn't be consistently achieved, thus a VCXO using a 11.92MHz crystal and multiplication to 95MHz was eventually designed in, giving very reliable locking.

Applying FSK to the VCXO (outside the loop bandwidth) gave very poor results, which was perhaps to be expected as it upset the stability of the loop despite adjustment of the loop time constants to compensate. So, it was eventually decided to adopt on-off keying by PIN diode switching of the drive to the 12GHz amplifier. The main advantage of this is that it leaves the main frequency determining section of the beacon untouched so stability is not impaired, but does have the slight disadvantage of having a spacer wave about 20dB down, due to 12GHz feed through the amplifier in the "off" state. At anything less than an S9 signal it is not noticeable.

It was decided not to have the weighty "brick" in the head unit, and to give it the benefit of the temperature controlled environment of the equipment bunker. Thus only the 24GHz circuits are located at the mast head. This does mean feeding 12GHz up the mast and this was done in LDF-450 heliax. Despite the heliax being beyond its specification at this frequency, the signal emerges to drive the 12/24GHz multiplier at +10dBm. A surplus 500mW Toshiba amplifier module was used to produce, in practice 800mW into the antenna at 24GHz. 12 volt power to the head unit is also fed up the coax.

The bulk of the equipment including the synthesizer, frequency generator brick, keyer, Switch Mode PSU etc. is housed in a 2U rack-mounting shelf in the equipment hut. The head unit containing all the 24GHz circuits is mounted in a diecast box with a lid seal and heatsink Since power consumption of the power module is around 5 Watts, it was thought that heat dissipation might be a problem, but with the power module bolted to the box wall and an external heatsink, the temperature rise is minimal. A temperature sensitive switch is provided to cut the 12V supply should the box temperature rise above 70C in very hot weather. A length of PTFE tube provides a radome for the slotted waveguide antenna. The antenna itself is based on a design in Dubus 1/1984 by DK2VR.

Other Beacons and Telemetry

An experimental beacon at 47.088905GHz built by G8ACE and G8BKE, is also mounted at the masthead, and is activated from time to time on command. A 1.3GHz beacon was not provided as GB3IOW on the Isle of Wight is Line of Sight and provides good coverage of the South coast.

Apart from the principal beacons described, telemetry is transmitted on 70.031MHz, using the callsign G4JNT/P, running 0.3W to a horizontal dipole. The format is slow CW which can be read on a PC, with conventional-speed summaries transmitted at regular intervals

WLAN Connection and Data Logging

Data from the telemetry module is logged with a low-spec PC running Linux – the processor speed in the PC is 100MHz and it only consumes around 45 watts. A routine polls the serial port and parses the incoming string which contains data from the Telemetry microcontroller. When this has passed its validation it is stored into separate database files which are updated every five minutes. Apart from the mains voltage / current, several other parameters are logged, including internal and external temperature via I2C sensors, battery charge voltage and PSU heatsink temperature, wireless link parameters including SNR, signal, noise, bit rate and lost packets. Four digital inputs are monitored for alarm purposes. The facility also provides video capture to allow remote video frames to be transmitted back from the hill top.

There is an 802.11b wireless LAN link from the beacon site which transmits database changes once per five minutes – at the other end of the link, another database is kept in sync and the data is read from this 'backup' database and secure copied over to the www.scrbg.org server, then rendered graphically such that trends can be spotted. So as to keep the wireless LAN link legal and within the 100mW EIRP, separate Tx and Rx antennas are used at each end of the link.

The receive side is passed through a band pass filter and a low noise GaAs FET preamplifier. In order to keep the SNR reasonable, the link is run at 1 or 2 Mb/s, which is far more than needed, but is the minimum speed for 802.11b networks. The Linux PC has a home-built watchdog card that receives a 'pat' from the user program every one minute – failure to receive three consecutive pats means that the Kernel or user-space has locked up which triggers a reboot of the system. The disk file system is journalised such that unexpected power failures do not result in an unrecoverable disk partition. The PC is also protected by a separate UPS which will run for around 6 to 7 hours before issuing a shut down command to the PC. The PC power supply has been modified to provide a soft-start when the mains supply reappears after a power failure.

Observations

Since becoming operational in May 2002 there have been numerous reports of reception from amateur stations throughout the UK and into mainland Europe. The site has proved to be capable of providing long distance propagation on all bands up to and including 24GHz, where several instances of 59+ reception have been reported at distances greater than 200km. This is all the more remarkable as the path is fully overland, and no doubt due to an elevated low loss duct. Many reports relate the reception at distant locations with comparisons made between several bands, revealing how different "lift" events support different frequencies. The frequency accuracy of the GPS disciplined sources has enabled many contacts to occur by providing a calibration reference for other stations.

The South Coast Repeater & Beacon Group have a well maintained website thanks to M0EYT and G6NLC, where details of the system and daily system parameter data can be viewed. Signal reports can also be logged and are much appreciated.

Acknowledgements

SCRBG consists of many like-minded microwave amateurs and the success and ongoing viability of this Beacon complex is due to their numerous contributions:

Specific thanks are due to the members and committee of the Flight Refuelling Amateur Radio Society for their ongoing financial contribution, and allowing our fund raising junk sales (surely recycling ?) at the annual Hamfest events.

To put things into perspective, the annual rental of the site is currently £500 and electricity is consumed at the continuous rate of 250W.

And last but not least :

To Sue, G7MHO – XYL of G0API – for food and drink every weekend and putting up with hoards of people passing through and building microwave hardware all over the house and garden.

The Bell Hill beacons and SCRBG have a dedicated web site at
www.scrbg.org

References

1 Modified N Connectors for Heliax	**RSGB Microwave Handbook Vol 2 page 8.3.** Details can also be found in '**The Microwave Newsletter Technical Collection', RSGB**
2 T7F UHF Transceiver Module	www.baycom.org/bayweb/tech/t7f/T7F-Engl.PDF
3 GPS Disciplined Oscillator **References**	http://www.scrbg.org/g4jnt/SimpleGPSDO.pdf
4 Microwave PLL	www.ham-radio.com/wa6cgr/mwpll.html

If you would like to financially help the beacon complex, please send a donation made out to SCRBG via the Keeper, G0API, QTHR.

Alternatively, visit the SCRBG website at the URL given, and make your donation via *PayPal*.

We hope to add to the RF available from this site – any suggestions will be considered and any offers of help or equipment donations welcomed.