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SUBJECT	Low VHF Multi-band Beacon		
Society	RSGB	Country:	UK
Committee:	C5	Paper number:	CT08_C5_24
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Introduction

This paper covers the rationale behind the deployment of a multi-band low VHF beacon in the UK. It proposes that further clusters are deployed and that the signals are actively monitored to improve our understanding of VHF ionospheric propagation. Annexes to this document provide information on the design and transmission format of the GB3RAL beacon cluster and a summary of reports received during the testing phase in Summer 2007.

Background

A major enhanced propagation mode at low VHF is via ionospheric refraction, either via Sporadic E or at solar maximum via the F2 layer. These propagation modes show a strong frequency dependence. VHF operators are known to monitor signals between 30 MHz and 144 MHz in order to predict when band openings are likely. While there are many beacons operating in the low VHF amateur bands around 28, 50 and 70 MHz there are very few beacons operating all from the same site and there are large gaps in frequency between the amateur bands.

To address this, a multi band beacon cluster has been installed at the Rutherford Appleton Laboratory in Southeast England. This beacon transmits with 10W EIRP at 40.05 MHz, 50.05MHz, 60.05MHz and 70.05 MHz and complements the 28.215 MHz beacon also on site. This effectively allows receiving stations to assess current ionospheric propagation state in 10 MHz steps from 30 MHz to 70 MHz. The beacons are also co-sited with the Chilton Ionosonde, and a 5.29 MHz experimental beacon. The beacons were installed for testing in August 2007 and several reports of reception have already been received.

Experience with the 5.29 MHz experimental beacon has demonstrated that automated beacon monitoring stations are now very much within the reach of amateur operators using of software defined radio (SDR) techniques and are able to contribute quantitative reception data to propagation studies. The 40 – 70 MHz beacons have been designed using advanced techniques to aid in their detection; the 28.215 MHz beacon is currently being upgraded.

Details of the construction and transmission format are presented in Annex 1. A summary of unsolicited reports of beacon reception is presented in Annex 2.

Key points and proposal

It is proposed that other administrations press for the construction and deployment of similar beacon clusters and that these be located at similar frequencies using compatible transmission formats. In particular the deployment of beacons should be encouraged in the 40 MHz region as this fills an important gap between the 28 MHz and 50 MHz bands. It is also proposed that automatic monitoring techniques are further developed and that amateurs are encouraged to install automatic reception systems and contribute the results to the community.

Recommendations

Noting:

1) That the deployment of beacon clusters at low VHF is of great benefit in propagation studies but that the relatively large frequency spacing between amateur bands at VHF hinders these studies

2) There are currently very few reliable signal sources transmitting easily monitored signals at appropriate frequencies between amateur bands

3) That recent developments in digital signal processing facilitate the construction beacons with greatly enhanced capabilities

4) That automatic beacon signal strength reporting using software defined radio is now practical and reports can be rapidly disseminated via radio and wired networks.

Recommends:

1) Administrations should encourage the deployment of multi-band beacon clusters covering low VHF between about 30 MHz and about 70 MHz.

2) Deployed beacon clusters should wherever possible provide signals at around 40 MHz and around 60 MHz.

3) Amateurs should be encouraged to set up and maintain automated monitoring stations and to contribute the measurement results to the community.

4) A common transmission format should be adopted to aid the reception of multiple clusters

Annex 1

The Rutherford Appleton Laboratory (RAL) is located at Chilton in South Oxfordshire and has been running since the 1930s and professional radio related research work continues covering the whole radio spectrum from LF up to optical frequencies. Following negotiations between the RSGB and Ofcom, RAL received permission to install a set of four beacons at 40/50/60/70 MHz. There are now six beacons operating under the callsign GB3RAL; these are shown in Table 1.

Frequency (MHz)	Antenna	EIRP (dBW)	Polarization	Max Height (m agl)	Locator
5.290[1]	Dipole	10	Horizontal	15	SU47508610
28.215[2]	¼ wave	10	Vertical	3	SU47458600
40.05[3]	Halo	10	Horizontal	20	SU47658610
50.05[3]	Halo	10	Horizontal	21	SU47658610
60.05[3]	Halo	10	Horizontal	20	SU47658610
70.05[3]	Halo	10	Horizontal	22	SU47658610

Table 1: Current GB3RAL Beacons

Specifications

At the outset in order to provide a reliable facility several specifications were set that had to be met. Frequency, power, antennas and shutdown requirements were specified in the license. Other significant specifications were.

Spurious outputs and harmonics

Because of the location and because of the use of non-amateur bands, the spectral purity of the beacons needed to be very high.. The level of both harmonic and non-harmonic spurious outputs was to be as low as practically possible and a maximum level of –60 dB with respect to the wanted signal was set.

Frequency and timing accuracy

For automated measurement and for weak signal detection the frequency of the VHF beacons must to be accurate. Keeping frequency drift under 1 Hz is desirable. This is 1 part in 10^8.

Antennas

The antennas had to be very durable. Amateur class antennas are frequently not durable enough for installation on commercial sites. One can imagine what might happen if one of our antennas fell off a tower and caused injury or damage.

1 An experimental 60 m band beacon operating as part of the 5 MHz NVIS experiment.
2 This beacon is the oldest on site and was originally located at Slough. An upgrade of this beacon is planned to improve reliability and frequency accuracy.
3 The new four band beacon, operating continuously at 40.05, 50.05, 60.05 MHz and 70.05 MHz.

The design

A modular design was developed and this is shown in Figure 1. This consists of a GPS based frequency and timing source, a set of four DDS signal sources, four high power amplifiers combined into two pairs to save rack space and a common oversized power supply.

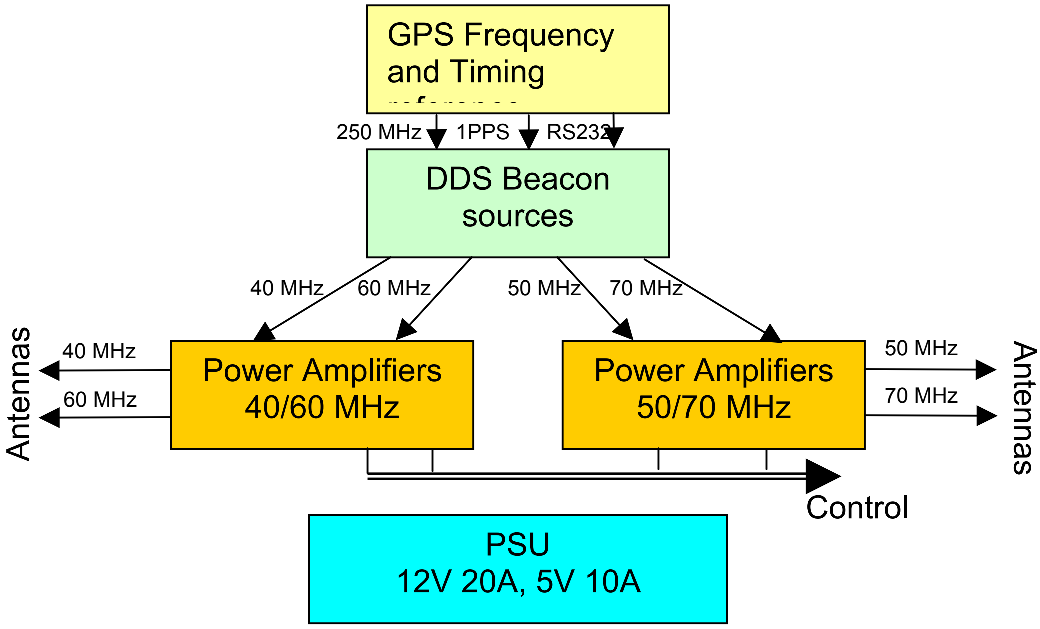

Figure 1 - Block Diagram of multiband-beacon

The entire system is driven by a GPS receiver which controls a 10 MHz ovenised frequency reference to around 1 part in 10^{10}. This receiver also produces the RS232 signalling of time and the one pulse per second signal which are used by the timing software. A low phase noise 250 MHz VCXO is locked to the 10 MHz GPS reference using a Reflock II designed by CT1DMK[4] with the 120 MHz input range extended using a pre-scaler. The frequency stability of the reference exceeds our ability to measure it. The error is less than 1 Hz at 70 MHz.

The beacon signal generating unit contains four signal source PCBs based on the AD8952 chip and designed by G4JNT. A PIC microcontroller controls each DDS using the timing data provided by the GPS RS232 and one pulse per second outputs. To avoid any key clicks, the keying waveforms are shaped using a 16 point root raised cosine function.

The RF output of each source is filtered and then amplified to 10W by a high power linear amplifier. Halo type antennas were uses as these are a light weight design with low visibility. The test configuration is shown in Figure 2. The eventual deployment site is 20m AGL on a local roof mounted tower shown in Figure 3.

[4] Reflock II – Now available from TAPR www.tapr.org

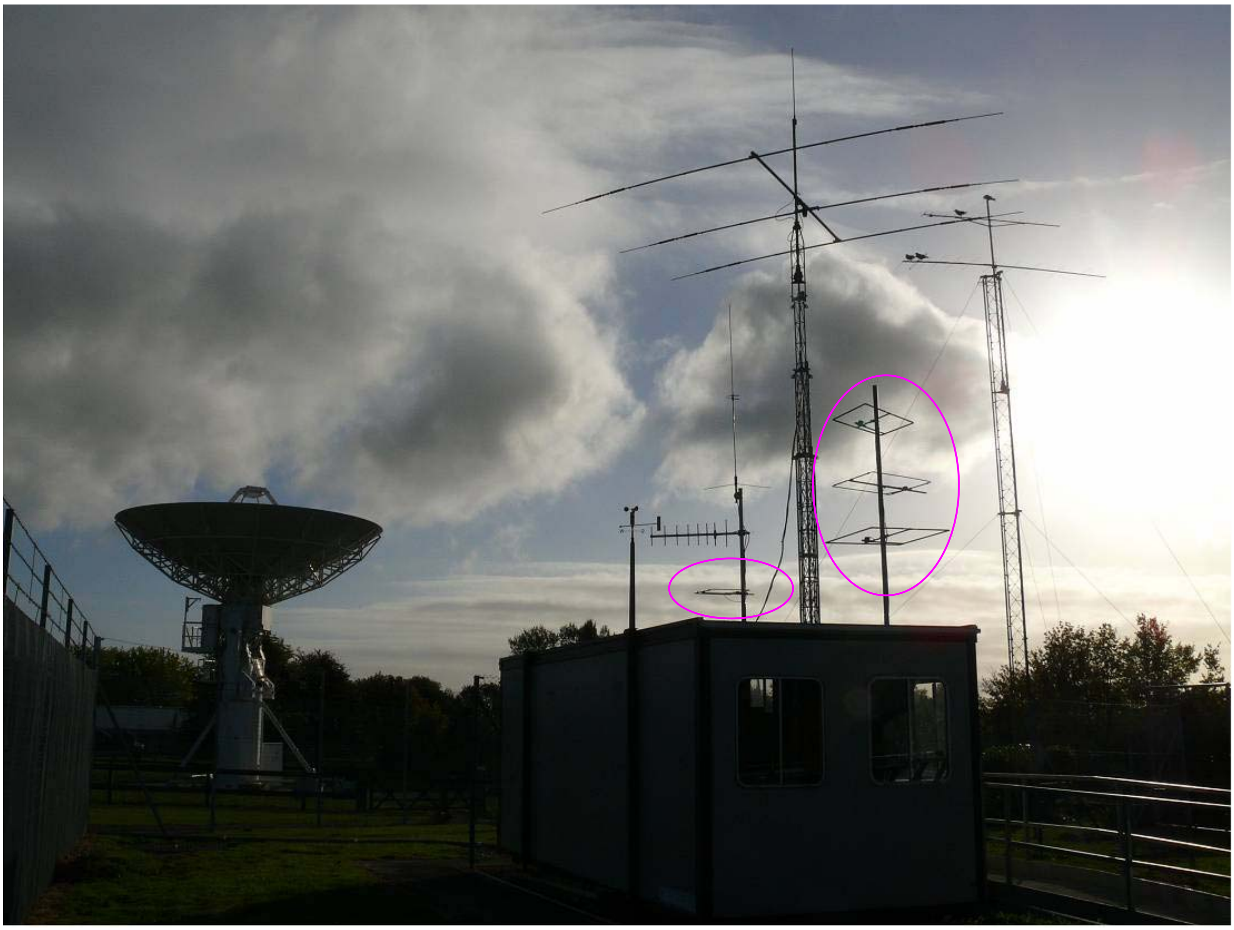

Figure 2 - Initial soak testing using temporary antennas

Figure 3 – 50 and 70 MHz Antennas and the view to the North East

The transmit sequence

As the modulation of the beacon is software defined almost any keying sequence is possible. Clearly CW keying of the callsign and locator is essential. Beyond this the JT65B weak signal mode developed by Joe Taylor K1JT[5], allows the beacon to be identified at significantly lower signal strengths than with a plain CW ID. This weak signal detection capability may show up interesting propagation effects and also partly compensates for the relatively low 10 W EIRP.

[5] Joe Taylor K1JT - http://physics.princeton.edu/pulsar/K1JT/

The current sequence is shown in Figure 4. It repeats every two minutes and includes CW and JT65B ID, a period of plain carrier and a period where the phase of the carrier is reversed each second as a timing marker and to assist in manual identification. Beacons that simply transmit a plan carrier with infrequent CW ID are difficult to distinguish from interference.

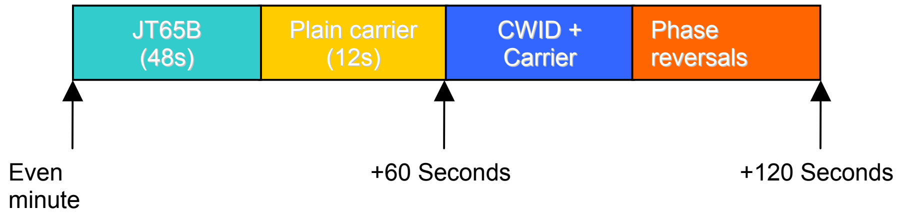

Figure 4 - Keying sequence

All the beacons start each two minute sequence together, triggered by a common signal. Differences between the arrival times of the start of the sequence at a distant site will be mainly caused by differences in the propagation channel.

Link Margins

Table 2 shows the assumptions made in calculating the link margins. Not many amateurs will have beam antennas or masthead pre-amplifiers for 40 or 60 MHz and this is reflected in the table. The minimum detectable signal level for the JT65B signal is taken as 16 dB in 1 Hz[6] and the transmitter parameters are taken from Table 1. The receiving antennas are assumed to be at roof height, 7m above the ground.

Frequency (MHz)	RX antenna type	RX antenna gain (dBi)	External noise factor[7] (dB)	RX noise figure (dB)	Overall noise power[8] (dBW/Hz)	Path loss capability[9] (dB)
40.05	Dipole	0	17	4	-183	167
50.05	5 element	9	15	1	-188	181
60.05	Dipole	0	13	4	-187	171
70.05	7 Element	11	11	1	-192	187

Table 2 – Link budget assumptions

The tropospheric path coverage of beacons where one might expect to be able to detect the beacon for most of the time has been predicted using the latest ITU-R recommendation P.1812 and are shown in Figure 5 and broadly agree the reports. While these coverage areas may appear disappointing in comparison to say GB3ANG or GB3VHF, it must be remembered that

[6] This figure comes from needing a 6 dB signal to noise ratio in the tone detection bandwidth of 10Hz. It is possible to improve on this through averaging several sequences. This level is also just about what is detectable by a skilled operator by ear.
[7] ITU-R Recommendation P.372-8, Quiet rural location. Very roughly the minimum noise is 30 dB at 10MHz falling to 8 dB at 100 MHz. This can be interpolated as a straight line on a log-log plot. Add 20 dB for town centre location.
[8] This is assuming a lossless antenna and any contribution from the feeder loss is included in the receiver noise figure. This is a reasonable approximation at VHF. Noise power (dBW) in 1Hz = Total noise factor – 204 dB.

[9] EIRP + Receiver Antenna gain – Required SNR – Noise power

the tropo coverage is not the main aim. We are more interested in Ionospheric paths, however, the path loss capability should be easily enough for the beacons to be detected when propagated by a low loss ionospheric mode, for example sporadic E. It is expected that currently sporadic E will give the longest ranges and at solar maximum we might expect worldwide F-layer propagation.

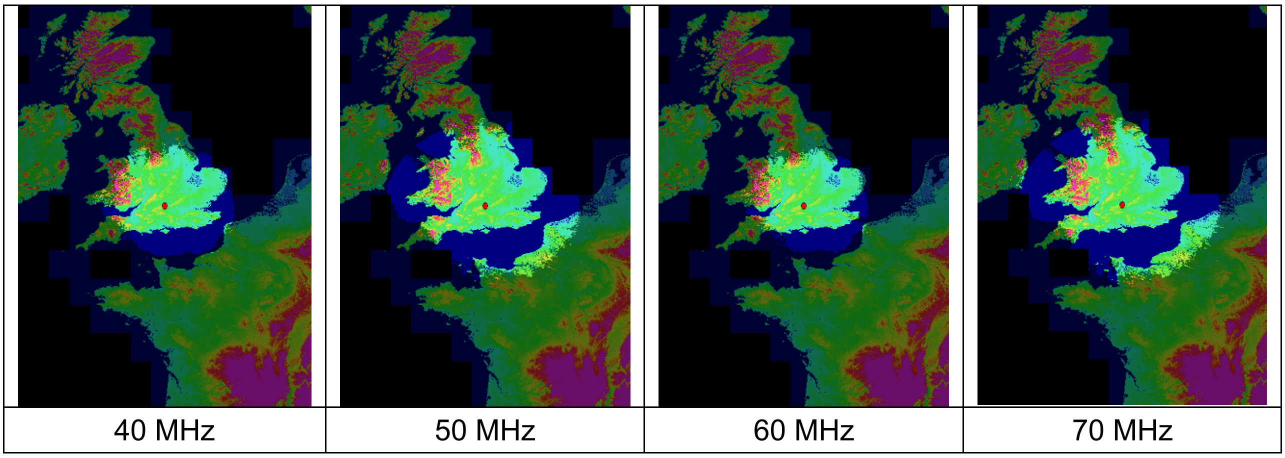

Figure 5 – Median coverage predictions based on Tables 1 and 2

Acknowledgements

The GB3RAL beacons could not exist without the support of several groups and individuals. The Rutherford Appleton Laboratory through the radio club, G3RRS provide the site and Ofcom have permitted the transmissions, which the RSGB beacons committee negotiated. G4JNT did much of the hard work in designing and producing the DDS signal sources. The UK six metre group provided power amplifier modules for 50 and 60 MHz. GH Engineering via G8UBN sponsored the 70 MHz power amplifier. John Wright, G3VPW provided assistance and antennas to this project and has been responsible for maintaining the HF beacons also on site.

Annex 2 – List of reception reports

The following lists are reports via DX cluster from the testing phase in August 2007. All beacons were operating but the using temporary antennas and lower power

G7RAU	70050.0	GB3RAL/B	IO90IR(TR>IO91IN 599, fb	0027	13 Aug 2007
G7RAU	50050.0	GB3RAL/B	IO90IR(TR>IO91IN 559	0525	13 Aug 2007
ES1GE	28215.5	GB3RAL/B	579 in KO29	0755	13 Aug 2007
DI2AL	70050.0	GB3RAL	long bursts 559 MS	0759	13 Aug 2007
CT1FFU	40050.0	GB3RAL/B	JT65a and CW 599	1315	13 Aug 2007
DI2AL	70050.0	GB3RAL/B	529 Es	1637	13 Aug 2007
EA4TX	28215.9	GB3RAL		2156	13 Aug 2007
SM0NCL-@	28215.0	GB3RAL/B	io91-jo99 41	2200	13 Aug 2007
IW4BET	28215.0	GB3RAL/B	579 >jn54	0645	15 Aug 2007
F6EGV-@	28215.0	GB3RAL/B	559 in JN33AQ	0711	15 Aug 2007
DJ7KG	28215.5	GB3RAL/B	JN39UR(ES>IO91IN 559	0828	15 Aug 2007
DJ7KG	28215.5	GB3RAL/B	JN39UR(ES>IO91IN 599+20	1116	15 Aug 2007
SM2LIY	40050.0	GB3RAL	539 KP03bu(ES>IO91in	1745	16 Aug 2007
SM2LIY	40048.5	GB3RAL	JT65B	1753	16 Aug 2007
DH6JL	40050.9	GB3RAL	JO31NI(TR>IO91IN 539 cw-mode	1806	16 Aug 2007
G7RAU	40050.0	GB3RAL/B	IO90IR(TR>IO91IN 529 deep qsb	1820	16 Aug 2007
HA1YA	40050.0	GB3RAL/B	bursts	1825	16 Aug 2007
DI2AL	40050.0	GB3RAL/B	579 Es	1154	17 Aug 2007
DI2AL	70050.0	GB3RAL/B	579 Es I call 69995	1230	17 Aug 2007
G7RAU	60050.0	GB3RAL/B	IO90IR(TR>IO91IN 539 wid 5ely	0604	18 Aug 2007
G7RAU	40050.0	GB3RAL/B	IO90IR(TR>IO91IN 529 wid 4ely	0605	18 Aug 2007
G7RAU	50050.0	GB3RAL/B	IO90IR(TR>IO91IN 539 wid 4ely	0606	18 Aug 2007
G7RAU	70050.0	GB3RAL/B	IO90IR(TR>IO91IN 589 wid 5ely	0606	18 Aug 2007
S57S	28215.0	GB3RAL/B	TNX RSGB for this Beacon 599	0815	20 Aug 2007
SK2AT	40050.0	GB3RAL	539 CW & JT65	1406	21 Aug 2007
I0JX	70049.0	GB3RAL	beacon in JT65A mode !?!	1719	21 Aug 2007
SM0NCL-@	28215.0	GB3RAL/B	io91->jo99 55	1919	21 Aug 2007
LA5HE-@	28215.0	GB3RAL	UK beacon strong tonight	2125	21 Aug 2007
SM2LIY	40048.5	GB3RAL	JT65B msg GB3RAL IO91IN	0755	22 Aug 2007
SM0NCL-@	28215.0	GB3RAL/B	io91->jo99 51	0844	22 Aug 2007
ES1A	28215.8	GB3RAL/B	599 in KO29	0637	23 Aug 2007
IN3RSV	28215.6	GB3RAL	Beacon 579 qsb - Es -	0710	23 Aug 2007
DI2AL	50050.0	GB3RAL/B	559 Es	0731	23 Aug 2007
DI2AL	40050.0	GB3RAL/B	559 Es	0732	23 Aug 2007
DI2AL	70050.0	GB3RAL/B	599 Es	0744	23 Aug 2007
9A8A	50050.0	GB3RAL/B	io91in/599/jn86eh	1053	28 Aug 2007
SM0NCL-@	28215.0	GB3RAL/B	io91->jo99 53	1903	28 Aug 2007
YU1FE	28215.8	GB3RAL	bcn io91 559 qsb	1107	03 Sep 2007
DH2UAK	50050.0	GB3RAL/B	IO91(ES>JO71 529	1252	03 Sep 2007
HA6NL	50050.0	GB3RAL/B	579	1705	10 Sep 2007
CT1HZE	50050.0	GB3RAL/B	519 1st time hrd	1956	10 Sep 2007
9A1CCY	50050.0	GB3RAL	599 in jn85	0644	11 Sep 2007
F6EGV-@	28215.0	GB3RAL	Bcn 529 in JN33AQ	0749	12 Sep 2007
F5TMJ-@	28215.0	GB3RAL/B	589 strong es	0752	12 Sep 2007
GW3TKH	70050.0	GB3RAL/B	519 IO91>IO81	1030	20 Sep 2007
CT1HZE-@	50050.0	GB3RAL/B	doodle 52	1152	24 Sep 2007
CT1HZE-@	70050.0	GB3RAL/B	579 Es!!	1225	24 Sep 2007
CT1FFU	50050.0	GB3RAL	CW and JT65 599	1255	24 Sep 2007
CT1HZE	50050.0	GB3RAL/B	559 Es	0909	25 Sep 2007

Reports from after installation of 50 MHz and 70 MHz on the tower but before the re-installation of 40/60 MHz.

EA5EF-@	28215.5	GB3RAL	IM99--IO91 weak	1044	14 Oct 2007
OH5LK	50050.0	GB3RAL	bcn IO91RL 569 KP30ON	1324	18 Oct 2007
G0UWK-@	70485.0	GB3RAL/B	Tropo 599 n=419	1628	19 Oct 2007
CT1FFU	50050.0	GB3RAL/B	JT65 beacon 599	1306	23 Oct 2007
CT1FFU	70050.0	GB3RAL/B	599 Es	1314	23 Oct 2007
CT1HZE	50050.0	GB3RAL/B	559 Es	1023	24 Oct 2007
IW0HBY	28215.0	GB3RAL/B	579 but intruders qrm	0936	26 Oct 2007
CT1HZE	50050.0	GB3RAL/B	559 Es	1201	26 Oct 2007
CT1HZE-@	50050.0	GB3RAL/B	599 Es	1207	29 Oct 2007
F6EGV-@	28215.0	GB3RAL/B	539 in JN33AQ	1350	29 Oct 2007
CT1HZE	50050.0	GB3RAL/B	539 Es	1012	30 Oct 2007
CT1HZE	50050.0	GB3RAL/B	579 Es	1034	31 Oct 2007
DH6JL	50049.7	GB3RAL	QRG +Call correction	1543	01 Nov 2007
G3IOI-@	70050.0	GB3RAL	Beacon IO91IN good sig in JO01	2059	04 Nov 2007
IK2WXQ	28215.3	GB3RAL	55	1244	09 Nov 2007
DJ7KG-@	28215.6	GB3RAL/B	JN39UR(ES>IO91IN 599 QSB	1059	12 Nov 2007
CT1HZE	50050.0	GB3RAL/B	559 Es	1128	14 Nov 2007
CT1HZE	50050.0	GB3RAL/B	539 Es	1150	23 Nov 2007
CT1HZE	50050.0	GB3RAL/B	539 Es	1252	18 Dec 2007
IN3RSV	28215.5	GB3RAL/B	Beacon 559 QSB - Es -	0926	19 Dec 2007
F6EGV-@	28215.0	GB3RAL/B	539 in JN33AQ	1237	19 Dec 2007
G4FRE	70050.0	GB3RAL/B	io91>io82uc	1333	25 Dec 2007
SP3RNZ	50050.0	GB3RAL	s5-s9 qsb	1543	26 Dec 2007
CT1HZE	50050.0	GB3RAL/B	519 Es	1734	27 Dec 2007