Connect Systems CS700 UHF DMR handheld

A look at the Digital Mobile Radio standard and an affordable digital handheld for that system

INTRODUCTION. Digital voice appears to be coming of age in the VHF and UHF bands so in this review I'll provide a view of the technology and a more detailed look at the new CS700 handheld from Connect Systems.

ABOUT DIGITAL VOICE. Until comparatively recently, the only viable digital voice product available to radio amateurs was the open source D-Star system that has been heavily supported by Icom. That situation has changed completely and the radio amateur now has a choice of three different VHF/UHF digital voice systems. Whilst choice is usually a good thing, in this case it also brings confusion as a cursory look at the three systems might lead you to assume that they may be interoperable. Despite the many similarities between D-Star, Yaesu System Fusion and Digital Mobile Radio (DMR), they are, in fact, wholly incompatible! Like many markets where multiple standards exist (eg Mac vs PC vs Linux), the user has to commit to one system. At the moment there is not much independent guidance available so the decision is not an easy one. For many entering the digital voice market the choice will be primarily driven by their local repeaters. This is because many of the benefits of the various digital systems are linked to the networking that is provided by the repeater infrastructure. This networking provides the facility to work amateurs from around the world using a low power handheld whilst sat in the garden!

DIGITAL VOICE TECHNOLOGY. One of the most important characteristics of all digital communications is its ability to transfer information with no loss or degradation to the original data. From the point of view of digital voice, that means the audio quality can be as good at the edge of the coverage area as it is right next to the repeater. The not so good aspect of digital signals is that they completely break up when you reach the coverage limit, whereas an analogue signal will usually give plenty of warning that the path is worsening before total loss of communications. This loss-free transport of the digital link is accomplished by digitising the audio signal and then ensuring that the resultant numbers representing the signal arrive at the distant end without change. As a result, the reconstructed audio signal will be very close to the original.

DIGITISING THE VOICE. The first and vital stage of any digital voice system is to convert the analogue voice signal from the microphone into a digital format. The most obvious way to do that is to use a simple analogue to digital converter (ADC). As ADCs are a vital building block in most digital systems and there is a huge range of ADC chips available. As you will know from analogue rigs, we don't need the full 20Hz to 20kHz audio range of the (young!) human ear to resolve speech and it's not

PHOTO 1: The Connect Systems CS700 has a good display and clearly labelled alphanumeric keypad.

uncommon to restrict the top end of the audio range to 2.8kHz or less. The extreme low frequency end is also unnecessary and communications audio usually starts at 300Hz, thus giving us a 300Hz to 2.8kHz range to digitise. The common method of digitising any signal, including voice, is to record regular voltage measurements of the signal. The question, of course, is what is the minimum number of measurements or samples required to create an accurate representation of the signal? The answer to this question comes from papers published by Harry Nyquist in the 1920s and the later classic *The Mathematical Theory of Communications* by Claude Shannon. Commonly known as the Nyquist sampling theorem the answer is simply that the measurements must be made at a rate that is at least twice the highest frequency in the analogue signal. In our case that means the measurement or more correctly sample rate should be at least 5.6kHz, so for the sake of simplicity, let's assume a 6kHz sample rate. The other aspect to consider is the accuracy of each measurement as that will affect the size of the number required for each sample. As you probably know, computers like binary numbers and preferably in 8-bit chunks, known as bytes. Whilst 16, 24 or 32-bit measurements may be used for high quality consumer and broadcast audio, simple digital voice only requires 8-bit measurements and that gives a potential 256 values for each sample. Using the numbers I've suggested here gives us an ADC taking 8-bit measurements at 6ksps (kilo samples per second). That gives
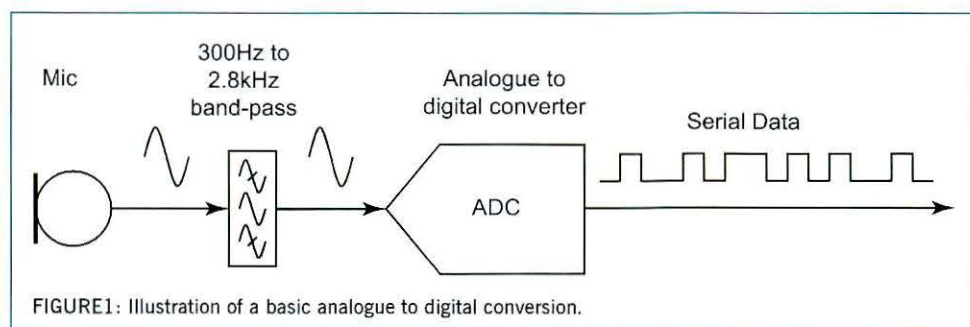

FIGURE1: Illustration of a basic analogue to digital conversion.

PHOTO 2: The top panel contains the antenna socket, a programmable button, channel & volume controls and a Tx LED. The belt clip is quite sturdy and just visible at the top of the panel is a moulding to take a lanyard.

a serial data rate emerging from the ADC of 48kbps (6kHz x 8 bits). I've illustrated the process in **Figure 1**. The problem here is that a 48kbps data rate signal is going to require more RF bandwidth than the original analogue voice signal! Clearly more work is required and the solution has been provided by the communications industry. Everyone from phone companies through to mobile radio manufacturers needs to make every ounce of bandwidth sweat so great efforts have been put into squeezing the human voice into as small a space as possible whilst maintaining intelligibility. As reducing the digital bandwidth of voice inevitable requires digital signal processing (DSP) technology the compression can be combined with noise reduction and other enhancements to create a complete voice processing unit that produces a signal that's ready for modulation and broadcast.

This unit is known as a vocoder (VOice enCODER). Although there have been lots of different designs, one reigns supreme and has topped many comparison tests. The winner is known as AMBE® (Active Multi-Band Excitation) and was originally developed at the Massachusetts Institute of Technology (MIT) but is now owned and licensed by Digital Voice Systems, Inc in the USA.

AMBE operates by splitting a segment of the digitised voice into a number of frequency bands that are each examined for signs of speech. Those without speech are discarded and those with speech are processed. This enables the vital elements of the speech to pass unhindered whilst eliminating noise and other unwanted artefacts. There are many other aspects to the processing but the end result is an encoded voice signal that will fit in an industry standard LPC-10, 2.4kHz digital voice channel, but with much better audio quality. Although 2.4kHz is the industry minimum, many systems, including some amateur digital voice allow a larger digital bandwidth to provide better speech quality. The three current amateur digital voice systems all employ the DVS Inc AMBE vocoder.

INSIDE DMR. The Digital Mobile Radio system is an open standard that was originally introduced to support the commercial Private Mobile Radio (PMR) market. The intention was to have a common standard that would allow the mixing of radios from different manufacturers on the same network. Whilst this has largely worked, inevitably some manufacturers have developed network enhancements that only work with same-brand radios. Of these enhancements, the Motorola MOTOTRBO system is one of the most popular and forms the basis of the amateur DMR network. Coordination of the amateur network is handled by DMR-MARC (Digital Mobile Radio – Motorola Amateur Radio Club) in the US. For the UK, we have DMRUK who provide advice and services to UK amateurs and are affiliated to DMR-MARC.

The MOTOTRBO system used for amateur DMR employs 4-FSK modulation along with time division multiplexing (TDM) to deliver two separate channels in a standard 12.5kHz RF bandwidth. The 4-FSK modulation system is illustrated in **Figure 2** and is a phase continuous system where the frequency changes occur at the zero crossing points. This provides for simple modulation circuitry and also allows the use of more efficient non-linear PAs that help to conserve battery power. The provision of two separate channels on the same frequency is achieved through time division multiplexing, where each channel is allocated its own timeslot and the two signals are then interleaved as shown in **Figure 3**. The result is two entirely separate channels on the same frequency.

DMR REPEATERS. Whilst most analogue repeater just repeat, digital repeaters usually include some interesting features that can transform your operating. The key factor is the use of internet links to join repeaters between different parts of the country and even other countries. All three amateur digital systems support this kind of linking but the DMR variant is probably the easiest to use. With DMR there is no setup as the connections are pre-established so the operator just has to decide which one to use. On repeaters connected to the DMR-MARC network the choice is: Worldwide, North America, Europe, Local S2, UK wide S2, Local S1, UK wide S1, English Europe S2, English Europe S1, Roaming, English WW. The S1 and S2 references relate to the time slot so English Europe has two channels available on time slot 1 (S1) and time slot 2 (S2). As you can see, you're really just setting the areas or zones you want to call. The commands to rebroadcast your call over a wide area are automatically sent to the repeater as part of the digital connection that carries your voice. For those areas where DMR take-up is slow, it is possible to set some repeaters for dual mode operation so they can handle both conventional analogue traffic as well as DMR calls. The downside of dual-mode operation is the loss of networking as you can't link a dual-mode repeater with the DMR-MARC network. The other important point about DMR networking is that you have to register for a free, unique ID for your radio. Registration can be via your local repeater group or via the central registration site [1]. I found the registration to be very quick and straightforward.
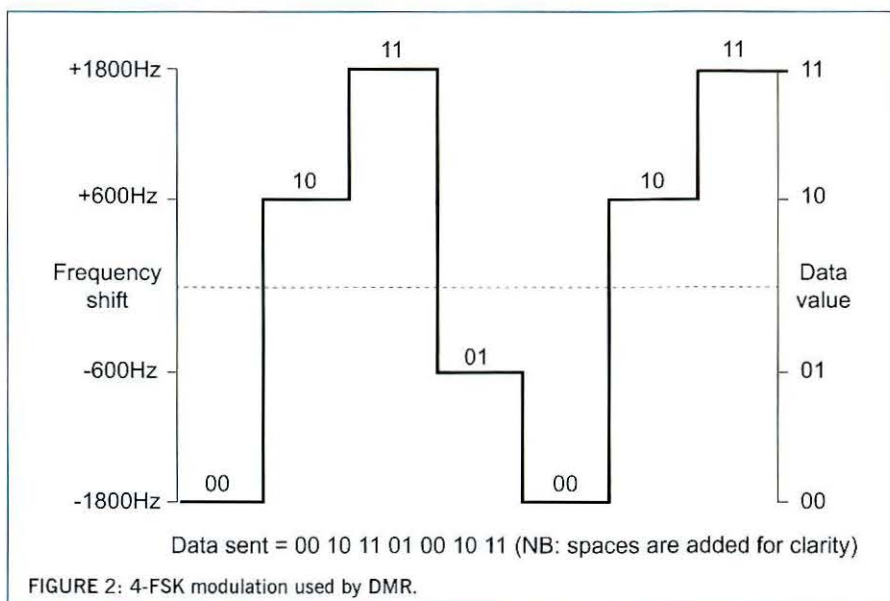

Data sent = 00 10 11 01 00 10 11 (NB: spaces are added for clarity)

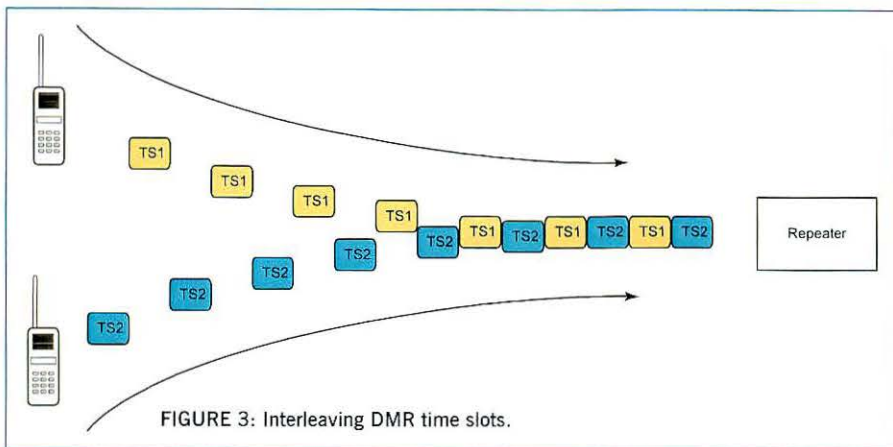FIGURE 2: 4-FSK modulation used by DMR.
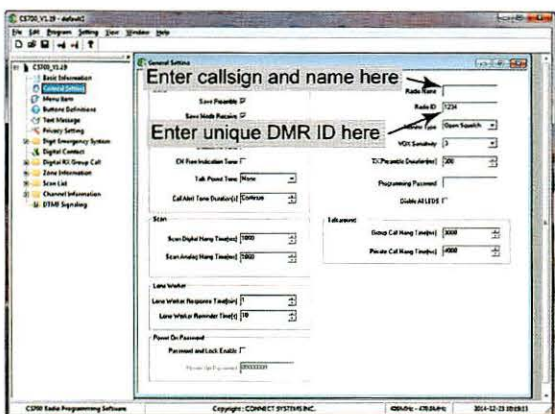
FIGURE 3: Interleaving DMR time slots.

FIGURE 4: Connect Systems CS700 programming software.

CONNECT SYSTEMS CS700. Let's now take a closer look at the CS700 to see what it's like to use. When I first unboxed the radio I was very impressed with the general feel of it. The construction was very sturdy and it looked like it could handle some pretty heavy use. This ruggedness is a common feature of DMR rigs as they are designed with commercial use in mind so they have to be tough to survive! Included in the pack was a desk charging unit with PSU, rubberised whip antenna, programming lead, sturdy belt clip and a printed instruction manual. The CS700 uses a 7.4V 1700mAh lithium ion battery that slides securely onto the rear of the radio. As you can see from the photos, the CS700 has just two rotary controls on the top panel and a set of alpha-numeric buttons on the front panel. The left-hand knob is a 16-position channel selector whilst the other is a conventional on/off and volume control. The main PTT button is located on the left-hand side along with two programmable

PHOTO 3: The radio sits snugly in its supplied drop-in charger.

function buttons. There is also a programmable button on the top panel. On the right-hand side is a substantial rubberised flap that provides access the external microphone and speaker jacks. This can be used with the optional fist mic for mobile or even base station operation. The supplied desktop charger held the radio very firmly and included an LED status indicator to show the charging progress. The review model was the UHF version that has 4W RF output on high power. There is also a VHF model available that features 5W RF output.

CS700 SETUP. Before you can use the CS700 on the network it first needs to be configured. In most cases this configuration will be completed by your supplier but the programming software is a free download and a programming lead is included with the CS700. The programming process is used to populate the CS700 memories with all the amateur repeater identities and operating frequencies. It is also used to store your unique network ID into the radio. I've shown a screen shot of the programming software in **Figure 4**. Although this might look a bit scary, you don't need to worry because in most cases all the major settings can be applied using a file known as a Code Plug. This is simply a data file that contains all the frequencies and operating details. For commercial operators, the Code Plug provides a simple way to ensure that all radios on a company network have the correct settings. Amateurs use it in the same way to ensure all radios have the correct repeater details.

The only settings unique to your radio are the name/callsign and the vital network ID. If you are planning to program your own rig, you should start by making a backup of the current settings save them on your PC. The programming software includes the facility to read the settings from the rig and save them as a custom Code Plug. By doing this simple back-up you will at least be able to return the radio to its supplied state if you get in a muddle! At the time of writing, Taylor Made RF have full CS700, VHF and UHF UK Code Plugs available for free download from their site [2]. In addition to populating the radio with simplex and repeater details, the programming software can be used to create pre-set text messages and to set the function for the CS700's three programmable buttons.

OPERATING THE CS700. With the setup complete, getting on the air was pretty straightforward. The first task was to select my local repeater by pressing and holding the left/right arrow key to bring up the menu, selecting Zone and then scrolling until I found a local repeater, which in my case was GB7SD, Dorchester. Finding the repeater was made easy because each entry included the local town name as well as the repeater callsign. This naming could be very helpful when operating away from home. At the time of the review GB7SD was not connected to the DMR-MARC network but the local repeater group were busy putting together a network of South West repeaters. This type of local linking is quite common with DMR so it's worth checking the plans with your local repeater group. Whilst visiting their website you might like to make a donation as the repeater groups rely on donations to keep the service running. When the desired repeater (Zone) had been selected, the channel knob on the top panel was used to select the appropriate call area, ie it was also easy to use the CS700 to scan for activity. As part of the Code Plug setup, each repeater entry has an associated scan list that's used to set the channels to be scanned.

Once I'd selected the repeater and checked it was free, a press of the PTT starts the transmitter. This was followed by a twiddly tone (talk permit tone) if the repeater signal was strong enough or a single low frequency beep if not in range. As I was in range, I could go ahead and make my call. That's really all there is to a basic call using one of the DMR repeater call areas. Provided you have an up-to-date Code Plug installed you should also see the other operator's callsign and name displayed on the screen. This was a very useful reminder if you're as hopeless as me at remembering names! Once you get familiar with the rig, it's

SPECIAL EVENTS STATIONS

These callsigns are valid for use from the date given, but the period of operation may vary from 1 - 28 days before or after the event date. Operating details are provided in an abbreviated form as follows: T = 160m; L = 80 or 40m; H = HF bands (30 - 10m); V = 6 and/or 4m; 2 = 2m; 7 = 70cm; S = satellite and P = packet. Details published here are kindly provided by Ofcom.

Date	Callsign	Phonetics	Location	Bands	Keeper
20/02/2015	GB2RSC	Radio Scouting Chesterfield	Chesterfield	TLHV27	GOTHF
21/02/2015	GB5WDG	Watton District Guides	Sahan Toney	TLH27	GOAJJ
22/02/2015	GB0PAX	Papa Alpha Xray	London	TLH27	G3YZO
24/02/2015	GB0FHG	Farnham & Hedgerley Guides	Stoke Poges	LH27	G4XDU
28/02/2015	GB2NCL	Newcastle	Newcastle	LH27	G4LIA

25 OCTOBER – 26th GREAT NORTHERN HAMFEST – Barnsley Premier Leisure Complex, Queens Road, Barnsley S71 1AN or follow the brown Metrodome signs. GNHF in association with SYRG. OT 10am, TS, SIG, C, FAM. Ernie, G4LUE, 07984 191 873. [www.gnhf.co.uk].

8 NOVEMBER – WEST LONDON RADIO & ELECTRONICS SHOW (Kempton Rally) – Kempton Park Racecourse, Staines Road East, Sunbury on Thames, TW16 5AQ. TI, free CP, OT 9.50/10am. TS, FM, B&B, SIG, C, DF, WIN, LEC. Paul, MOCJX, 08451 650 351, info@radiofairs.co.uk. [www.radiofairs.co.uk].

15 NOVEMBER NEW VENUE – CATS RADIO & ELECTRONICS BAZAAR – Coulsdon Community Centre, Chipstead Valley Road, Coulsdon, Surrey CR5 3BE. Limited on site parking (50), street parking available. OT 10am-2pm, £1 including a complimentary tea or coffee, B&B, C, DIS. Glenn, G4FVL, bazaar@catsradio.org.

15 NOVEMBER – PLYMOUTH RADIO CLUB RALLY – Harewood House, The Ridgeway, Plympton, Plymouth PL7 2AS. CP, TI, OT 10am, £2, TS, C. Sheila Hart, 2E0YSH, 07815 542 477, sheo@fsmail.net.

5 DECEMBER – SOUTH LANCS WINTER RALLY – Bickershaw Labour Club, Bickershaw Lane, Bickershaw, Wigan WN2 5TE. OT 9am, traders 7.30am. £2.50, B&B, C, DIS, CP, SIG, DF, TS, LB. Jason, 01942 735 828.

SILENT KEYS

We regret to record the passing of the following Members:

Name	Date
Dr G Brown, MW5ACN	10/12/2014
Mr D Buttimore, G1NMF	12/2014
Mr C J J Bittan, G1TBO	
Mr T Simpson, GM3BCD	25/10/2014
Mr L R V Mitchell, G3BHK	6/10/2014
Mr H E Richards, GI3DXU	24/11/2014
Mr J Dunnington, G3LZQ	8/12/2014
Mr J E Cronk, GW3MEO	22/11/2014
Mr A C Wadsworth, G3NPF	11/12/2014
Mr D G Bingham, G3VBD	17/11/2014
Mr S D Williams, G4RGX	22/11/2014
Mr G L Holdom, G4SVU	3/12/2014
Mr E Barr, GI7FFF	25/2/2014

SILENT KEY COLUMN ENTRIES
To notify the RSGB that a Member has passed away (and their subscription should end and they should be listed in Silent Keys), please e-mail sales@rsgb.org.uk or telephone 01234 832 700 and then select option 1. We will need to know the deceased's name, callsign or RS number and, if possible, date of death.

OBITUARIES
Oituaries are published at www.rsgb.org/sk. Please send submissions by e-mail (only) to sk@rsgb.org.uk. All submissions are moderated and may be edited for reasons of style, grammar, length etc. *Online obituaries are separate from the Silent Keys column.*

Review

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possible to use the CS700 to send simple text messages to a specific user and to initiate a private call. The latter is a call to a specific station that can be located anywhere on the network.

In addition to its DMR facilities, the CS700 is a dual-mode rig so can also be used for conventional analogue FM. To help with this the latest UK Code Plug includes analogue simplex and repeater frequencies. The RF performance of the rig appeared to be very good with plenty of sensitivity and no signs of overload even when used with an external antenna. Battery life is difficult to define as it is so dependent on the amount of transmit time.

The manufacturers claim 14 hours in digital mode and 11 hours in analogue but I found the life to be nearer 8 hours, which is still a very useful life.

The big question with any digital radio system is audio quality but this is something that's very difficult to convey in a few words. I strongly suggest that you listen to DMR before you buy. Here's my take on the sound quality. I found it to be very clear with good intelligibility and little to no audible background noise. However, the timbre of the voice is changed by the vocoder, making it difficult to hear the vocal characteristics that we use to identify individuals. The net result is that everyone tends to sound the same.

SUMMARY. There is no doubt that the CS700 is a very robust and extremely

PHOTO 4: Clear labels describe the transceiver and Li-ion battery.

competitively priced DMR radio that should help this mode to catch on. As mentioned earlier in the review, the key to success in any of the digital voice modes is the availability of repeaters and the DMR network is currently growing quickly. If you want to get into digital voice at low cost the CS700 could be a very good place to start. The Connect Systems CS700 is available from Taylor Made RF [2] and costs £199.99 including VAT at 20%. The rig is supplied with a free programming lead and software. My thanks to Taylor Made RF for the loan of the review model.

WEBSEARCH
[1] http://register.ham-digital.net/
[2] www.tmrf.co.uk/

TABLE 1: Specification summary.

Frequency Range	400-470MHz (UHF model), 136-174MHz (VHF model)
RF Power	VHF: 5W/1W, UHF: 4W/1W
Frequency stability	±1ppm
Analogue sensitivity	0.35μV for 20dB SINAD
Digital sensitivity	0.3μV for 5% BER
AF output	>1W
Battery	7.4V lithium ion
Dimensions	113mm x 54.4mm x 35mm
Weight	275g with battery and antenna