Long-range digital radio – the case for HF

Image credit: Codan Radio Communications

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From the editor ...

Image credit: Ocean Radio Communications

When you're far from home and cut off from communications infrastructures, HF radio is still the technology you can rely on to keep you in touch with the outside world.

HF is used extensively by militaries, disaster relief agencies, emergency services, security services, NGOs, exploration companies and particularly by aviation and maritime agencies and operators.

Modern HF technology is a far cry from that of its humble beginnings. Automatic frequency selection has taken the hard work out of making contact, and the arrival of digital technology and advanced signal processing has overcome the voice quality issues of the past.

One of HF's main strengths is that it doesn't depend on infrastructure such as towers, repeaters, cable networks and so on. It's an independent communication medium that can be operated from anywhere - including the harshest and most remote corners of the globe - and can be set up within minutes and used by operators who have had minimal training.

This eBook explains the concept of HF radio and describes the modern techniques that are being employed to keep it at the forefront of resilient, reliable communications networks.

As a former radio operator myself - accustomed to listening to scratchy, noisy HF comms - I can tell you that having seen and heard demonstrations of the new digital voice technologies, long-distance radio will never be the same again. HF is definitely here to stay.

Jonathan Nally

Editor

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HF radio - a backgrounder

Mike Smyth

HF radio has been with us from the start, and technological advances promise to keep it relevant for years to come.

High frequency (HF) radio was one of the first parts of the spectrum to be opened up in the pioneering days of radio. With frequencies stretching all the way from 3 to 30 MHz, there is almost always an 'open' channel with which to ensure reliable communications. In practice, most HF radios use from 1.6 to 30 MHz with the majority of long-distance communications being in the 4 to 18 MHz range, although higher frequencies may be used depending on the time of day and ionospheric conditions.

Unlike short-range VHF and UHF communications, which are line of sight (LOS) transmission technologies that can be blocked by mountains and buildings, and which cannot reach far (if at all) over the horizon, HF is far less unconstrained by terrain and distance.

Long-range HF communications rely on refraction of signals by the ionosphere. The ionosphere is an ionised region of the upper atmosphere between about 80 and 600 km in altitude. This region can be visualised as several distinct layers, most commonly referred to as the D-Layer, the E-Layer and the F-Layer.

Also often known as shortwave radio, HF was the backbone of most long-distance radio traffic right up until the 1990s. With the advent of satellite communications and the internet, HF became regarded by some as being yesterday's technology.

It was soon realised that satellites can be easily jammed or destroyed, and can irretrievably break down. Mobile phones depend on vulnerable land-based infrastructure, as do VHF and UHF radio systems.

But all an HF network requires is a transceiver at both ends - there's no need for intervening infrastructure. HF, coupled with component miniaturisation (which has reduced the size of transceivers), has taken on a new lease of life as an inexpensive and very reliable form of communication. With the adaption of modern techniques, HF has become an essential means of long-range communication - especially in times of disasters when more traditional communication systems are either destroyed or overloaded.

The inherent problems of HF - such as interference from other users, atmospheric noise, limited bandwidth - are being addressed with modern technologies. Link quality analysis is one technique where transmitting and receiving stations cooperate to assess the quality of the channels available and then select the best one. Another is automatic link establishment (ALE), which is a system that takes the guesswork out of selecting a suitable operating frequency.

Red Cross societies in New Zealand, Denmark, Spain and the USA are establishing HF emergency response units, designed to be easily operated by non-expert volunteers who can be deployed to a disaster area within 48 hours.

During times of natural disasters, from tsunamis to typhoons to bushfires, the value of HF is recognised by and increasingly used by utilities. And militaries have used HF since before World War II for both tactical and strategic communications.

Even at low power levels, HF can be used for LOS communications with a range of typically 30 kilometres depending on terrain, obstructions and earth curvature. Longer ranges will also be affected by operating frequency, power output and the height of the antenna. The restricted range reduces adjacent interference and makes possible high data rate transmission.

Radio signals in the HF band can travel distances of between 50 and 300 kilometres by being refracted from the bottom of the ionosphere and reflected from the ground - known as ground wave propagation. In certain circumstances such as over the ocean, multiple hops may result from this phenomenon, leading to distances of up to about 300 kilometres. Ground waves are usually used for analog voice; high data rates may be limited, although ground waves over water may lead to higher data rates. The effective range of this propagation mode is affected by factors including terrain, operating frequency, transceiver power output and directionality of the transmitting and receiving antennas.

Beyond-LOS, near-vertical-incidence skywave (NVIS) range can be increased to about 400 kilometres because terrain obstruction is not a problem when the frequency range is restricted to less than 10 MHz. When most of the radio signal propagates vertically it is refracted back to earth. A relatively large proportion of the signal is returned and as such NVIS is often used for high data rates.

The effective propagation range is influenced by factors such as transceiver power output, antenna directionality and frequency selection. ALE can help in solving frequency selection.

Long-range communications out to 4000 kilometres and beyond rely on the effective combination of antennas, power levels and atmospheric conditions. ALE can be very useful in this situation by sorting out suitable frequencies which often require directional antennas. Long-range skywave propagation is characterised by only a small proportion of the signal arriving at the receiver, hence is primarily used for voice and lower data rates. The effective propagation range is influenced by factors such as transceiver power output, antenna directionality and frequency selection.

HF is widely used by military and other governmental organisations, aviation air-to-ground (particular for oceanic and remote continental areas), shortwave services, amateur radio operators and some radar systems.

The latest technology is digital voice HF, which almost entirely does away with the often poor quality of reception due to static and other kinds of interference. Digital voice is commonly used to produce high-quality voice communications over LOS, ground wave and NVIS channels. Digital voice is also effective over long-range channels with only a slight reduction in voice quality.

Image credit: Codan Radio Communications

HF - the reliable choice for voice

Jonathan Nally

Whether in time of peace or war, natural disaster or humanitarian crisis, you can always rely on HF radio communications.

In all parts of the world - metropolitan or rural, baking desert or frigid poles - HF radio proves its worth every day. In use with security forces, humanitarian organisations, militaries, aviation agencies, maritime services and more, HF is often the only means of communication with the outside world.

HF's traditional advantages of long-range, non-reliance on infrastructure and ruggedness are today supplemented by technologies such as automatic link establishment (ALE) that take the guesswork out of establishing communications, improving ease of use.

Add to that the voice quality benefits that the latest digital voice technology brings and it's easy to see why HF remains such a potent communications medium.

In the field

More and more organisations are turning to HF to provide their back-up, or primary, means of staying in touch with agents and operators in the field, and with headquarters or regional command centres.

The Red Cross makes extensive use of HF, which is hardly surprising considering some of the remote areas the organisation reaches - regions that very often have no reliable communications with the wider world, either through lack of infrastructure or because of damage caused by natural disasters.

With ALE taking the hard work out of choosing frequencies and making contact, it is easy to quickly train unskilled operators to take control of communications. The Red Cross often leaves entire HF radio set-ups behind for locals to use, once the agency's main mission is done.

The clarity of digital voice also makes it easy for operators to hear what others are saying - a skill that can take some time to acquire when working with scratchy traditional analog HF.

When disaster strikes

It has been shown time and time again - Hurricane Katrina, the London bombings, the Christchurch earthquakes - that commercial communications cannot be relied on when a disaster hits. Consumer-grade mobile phones, the internet, even landlines can be put out of service by an earthquake, flood, fire or cyclone. Or, they become so overwhelmed with the public making calls that emergency services personnel cannot get through.

This is when you need a technology that is simple and reliable. With HF, all you need is a radio, a battery and an antenna - and within seconds you can be talking with colleagues tens, hundreds or thousands of kilometres away. There is zero reliance on vulnerable infrastructure. This is the beauty of HF.

US government goes HF

The US Department of Veterans Affairs recognises this, and so has announced its intention to deploy a resilient emergency HF network to connect medical centres spread throughout the USA.

The network will have 400-watt backbone stations designed to provide communications among 125-watt stations and 125-watt mobile vehicle-based stations located at approximately 200 Veterans Health Administration (VHA) facilities.

The network is to provide voice and data communications, as well as patching into land and cellular telephone services, using ALE.

Other US departments have similar HF systems. The Department of Homeland Security has a network known as SHARES and the Federal Emergency Management Agency, Army National Guard and Centers for Disease Control and Prevention all have their own emergency HF networks.

When all else fails

When a natural disaster strikes, standard communication with the outside world is one of the first things to go. Sometimes the only communications that remain are amateur radio set-ups operated by enthusiasts. Amateur radio uses HF for long-range comms, and while this eBook is not concerned with amateur or 'ham' radio, it is worth recalling how the experience of amateur operators perfectly illustrates the benefits of having standalone communications networks.

Time and again, amateur radio HF operators have stepped in to provide the only comms with the outside world. They were vital in the early stages of the Falklands Islands war, the Haiti earthquake, Hurricane Katrina and the terrible Indian Ocean tsunami.

US politician Mike Ross, a member of the House of Representatives, is one of only a handful of congressmen who is also an amateur radio operator. Commenting on the role of HF communications in the aftermath of Hurricane Katrina, he said: "Citizens throughout America dedicated to this hobby - a hobby that some people consider old-fashioned or obsolete - were true heroes in the aftermath of Hurricane Katrina as they were often the only line of communication available into the storm-ravaged areas. Flashier means of communication and technology are highly vulnerable. Ham radios, entirely self-contained transmitters, require no cell towers or satellites, simply a battery and a strip of wire as an antenna."

The Wall Street Journal said: "With Hurricane Katrina having knocked out nearly all the high-end emergency communications gear, 911 centers, cell phone towers and normal fixed phone lines in its path, ham-radio operators have begun to fill the information vacuum. 99.9% of normal communications in the affected region is nonexistent."

If amateurs can achieve all of this with simple gear at home, think of what a professional organisation such as yours could achieve with industrial-grade HF radio equipment - yet at relatively low cost, given that there is no need for extensive and expensive infrastructure.

The moral of this story is that HF communications are unencumbered by reliance on vulnerable networks, are able to reach virtually anywhere in the world and, with modern technologies incorporated, are as dependable, easy to use and clear as every other radio system.

Image credit: Codan Radio Communications

Digital voice for HF

Jonathan Nally

The last great drawback of HF radio - frequent poor voice quality - has now been overcome with digital technology.

HF radio has always had some weaknesses, such as susceptibility to interference, fading and dropouts due to ionospheric effects and frequent poor voice quality. But each of these has now largely been overcome.

Following experimental work in the 1980s, automatic link establishment (ALE) has become the de facto standard for HF communications. With ALE, radio units continually scan a number of predefined frequencies, known as channels, and periodically send small transmissions, known as soundings. Other radios on the network receive these soundings and use them to learn which stations can be contacted using which channel. When a call is initiated, the ALE controller automatically selects the best channel and sends a request signal to the recipient unit to establish a link. Once established, the two units can then communicate with each other. ALE can also support text messaging, and for higher bandwidth applications such as email, ALE can be used in conjunction with special modem waveforms which can reliably transfer larger amounts of information over HF.

ALE has greatly diminished the difficulties of selecting appropriate, reliable frequencies, and thus has reduced the problem of fadeouts and interference.

Perhaps the main weakness cited of HF, though, is poor voice quality that comes as a result of all manner of atmospheric effects (eg, lightning, the influence of solar flares and so on) and manmade interference from other equipment and radio transmissions. But with the arrival of digital HF voice technology and advanced signal processing, this too is becoming a thing of the past.

Loud and clear

Clear, intelligible HF voice communications is not only desirable … it can be the difference between life and death. The user might be a military unit in the field, calling for backup. Or an aircraft lost in a remote area, calling for assistance. Or a humanitarian mission 200 kilometres from the nearest hospital, calling for urgent medical aid. Reliable, clear comms are vital - you can't afford for your message to not be understood.

Digital voice technology is the answer. As operators of the digital VHF/UHF professional mobile radio (PMR) networks can attest, having upgraded from analog, the clarity that digital brings results in better communications, the virtual elimination of repeat calls (because the recipient didn't understand you the first time) and therefore more efficiency and responsiveness.

The same is now true of HF.

Digital voice works by taking an analog voice signal from a radio's microphone, digitising it and processing it using a vocoder. This

compresses the data stream to make it practical to send over the typically narrow frequency range being used. After the vocoder, the digital signal typically flows through a cryptography unit to ensure the signal cannot be eavesdropped on once it makes it to the final step, the transmitter and broadcast.

At the other end, modern receiver technology is employed to pick up weak signals that might have been sent from hundreds or thousands of kilometres away. The signal is then equalised, demodulated, decrypted and turned back into voice using an inverse function within the vocoder.

In addition to the modem technology allowing transmission of data over HF, the vocoder is the function which is responsible for the high-quality voice. A vocoder technology known as MELPe is most commonly used over HF, and supports voice coding rates of 2400, 1200 and 600 bits per second (bps).The MELPe algorithm was derived using several enhancements to the original MELP (mixed-excitation linear prediction) standard; it is also known as NATO STANAG 4591. MELPe also supports compressed bit-stream transcoding between the different rates. A noise pre-processor helps to reduce background noise; a post-filter provides further increase in the quality of speech reproduction.

MELPe is regarded as the industry benchmark; however, Australian company Codan Radio Communications now offers new technology, based on a vocoder known as TWELP, which provides improved voice quality using the same bandwidth. In quantitative tests of voice intelligibility, conventional analog voice has been shown to be intelligible down to below 10 dB signal-to-noise ratio (SNR). Codan's digital voice technology operates down to just 2 dB SNR at full rate (2400 bps) and at the lowest rate (600 bps) it operates below the noise floor, down to below -3 dB SNR. This practically translates to increased operating range and reliability, with reduced requirement to repeat messages.

This shows the power of digital voice HF radio.

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