Natural Radio

News, Comments and Letters About Natural Radio

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Recorders for Natural Radio Signals There has been considerable discussion on the VLF_Group of the various types of recorders and methods that can be used to record VLF signals, so I though that an article on recorders might be useful. Being in the studio business, I have been using various methods to record sounds for the past thirty years or so. When I started out, back in the 70's, recording was analog. In the studio we used large reel-to-reel tape machines and even had a disc cutter to cut masters for vinyl LP records.

I now do all recording digitally, both in video and audio. Manufacturers of the equipment and software want to produce the best sounding audio subjectively, even when heavy data compression is applied, such as for use over the internet. Systems such as the Sony Minidisk also compress the digital data to allow recording where storage space is scarce. However, equipment designed to produce great sounding audio might not always be that best choice for accurately recording VLF radio signals.

If you are recording signals to listen to, a system that records good sounding audio should produce good quality Natural Radio recordings. However if you are recording signals for later processing or analysis you need to be more careful in choosing a recorder, especially if you are considering some of the digital recording systems that use data compression, such as the Sony Minidisk.

There is a common myth that analog systems provide more faithful reproduction of the input signal because they bypass the conversions to digital and back to analog, but this is not necessarily true. Let's review what types of recorders are available.

Analog Recorders – Analog tape recorders like reel-to-reel machines and cassette recorders take the AC audio signal and convert it to a varying magnetic level on tape, which when played back by moving the tape across the playback head, produce a signal output that approximates the original.

A two-track reel-to-reel studio machine recording at 15 ips, might provide a signal to noise ratio of almost 70 db. Overall speed accuracy is ±.2%, wow & flutter at .1% Frequency response is 30 – 18,000 Hz. ±2 db.

A studio quality cassette recorder would have a S/N ratio of 55 db., overall speed accuracy of ± .5%, wow and flutter of .2% and frequency response of 35-14,000 Hz. ±3 db, measured at 20 db below maximum level. Recording at maximum level, the frequency response degrades to 35 -6,300 Hz. ±3 db.

A low-cost portable cassette recorder would have worse specifications, especially those that were mechanically related such as speed accuracy and wow and flutter.

Even a good studio reel-to-reel recorder will produce audible hiss on recordings, so noise reduction systems were developed to improve the S/N ratio. Two of the most popular systems are Dolby and dbx. These systems compress the dynamic range of the audio signal prior to recording, and expand it on playback, thus compensating for the poor S/N ratio of analog recording.

Dolby compresses the input signal only over a certain threshold and for it to work properly the record and playback levels of the tape must be set to match the threshold level of the Dolby unit. For good accuracy, the unit should be recalibrated each time you switch the brand or grade of tape you are using. Dbx compresses over the whole signal range and no level matching is necessary.

There is a price to be paid however. Both of these systems magnify the frequency response errors of the machine and can introduce distortion. Nevertheless, they are both good systems and can provide excellent results on well calibrated machines.

FM and Instrumentation Recorders – Instrumentation recorders were developed to overcome some of the disadvantages of analog recording. These recorders were usually reel-to-reel and recorded an FM signal on tape which allowed for the recording of ELF signals that were below the range of a regular audio recorder, such as mechanical vibrations and other low frequency signals in industrial and scientific applications.

Another type of FM recorder is VHS Hi-fi. The VHS Hi-fi FM signal is recorded along with the video in helical scan mode on the videotape and provides a low-cost method of high quality recording with low tape cost. S/N ratio is on the order of 90db, wow and flutter are very low, but as with all audio recorders, the frequency response is limited to 20 – 20,000 Hz.

This may be a viable option for high quality recording because of the long recording times available on VHS tape and low tape cost. Be careful, however, that you are recording and playing back from the Hi-fi inputs and outputs. All VHS Hi-fi recorders have the standard linear audio tracks for compatibility and if you use these by mistake your S/N ratio will drop to 40 db and frequency response will suffer.

If you have a high-end VHS Hi-fi machine there will be separate inputs for the analog and Hi-fi tracks, so it is possible to record WWV time signals on the linear tracks and your VLF signals on the Hi-fi tracks. VHS Hi-fi is also sensitive to tape dropouts.

Digital Uncompressed – Digital PCM (Pulse-code modulation recorders like DAT machines can provide the most faithful reproduction of any recording system. The incoming signal is sampled at a fixed rate and each sample is converted to a digital number of a certain number of bits. The more bits, the more accurate the reproduction.

Key factors here are the sampling rate and the number of bits resolution. DAT machines and Compact Disks sample at 44.1 kHz and have a resolution of 16 bits. Frequency response is flat form 20-20,000 Hz, wow and flutter are insignificant and the signal-to-noise ratio is on the order of 90 DB. Some of the new studio recorders

sample at 96 kHz and have a resolution of 24 bits. All of these systems are uncompressed – that is, each sample is recorded at full resolution.

You can also use the soundcard in your computer to do this type of recording and save the results to a wave file. Just make sure you are recording at 44.1 kHz sampling rate and 16 bit resolution, as most computers will allow you to set a lower sampling rate and a lower resolution.

It is possible to pick up noise in the computer from the soundcard, so you might want to experiment with different sound cards and with which slot it is placed in the computer.

Digital Systems that Compress Data – In order to be able to send audio over the web and to increase storage density of media, several systems have been developed to reduce the bit rate of a digital audio stream. The Sony minidisk, Real Audio, MP3 audio and Windows Media reduce the bit rate of an audio stream and thus the storage space required for audio file. These systems are optimized for music, and recognize the psycho-acoustic affects of human hearing and use sophisticated algorithms to remove parts of the audio that we can't hear and thus compress the data. These systems provide great sounding audio with a greatly reduced bit rate as compared to conventional PCM digital audio. They also provide varying amounts of compression determined by how much degradation you are willing to tolerate in the playback signal.

The little hand-held solid-state recorders used for dictation use a low sampling rate and heavy compression and in most cases are probably not useful for Natural Radio recording. (See Shawn Korgan's letter below.)

Remember that these systems were designed for audio recording and usually have a frequency response from 20 – 20,000 Hz. So for recordings below 20 Hz. you may need to modify the system or use a recording system designed for lower frequency use.

Other things in the audio chain can also distort your recordings, the most common being tape recorders with automatic volume controls. Running your signal cables near power lines, switching power supplies and motors in the recorders can all introduce noise into the recording process. You will probably want to keep your E-Field probe or your loop well away from the recorder to eliminate some of this noise pickup.

Conclusions - If you are recording Natural Radio signals that are audible, and you are recording them just to listen to, most consumer audio recorders will work well. Many of us have made excellent recordings with cheap portable cassette recorders. The noise floor of most listening locations is probably the limiting factor in the S/N ratio of a recording.

A minidisk recorder will provide a better S/N ratio, better frequency response, is probably easier to use and is available at a reasonable cost. The better speed accuracy will allow you to determine time of events better if you only place the time mark at the beginning of your recording.

However, if you need to make extremely accurate measurements of frequency or waveform; or if you are going to do extensive filtering to recover signals below the noise floor, then a PCM based system like DAT or recording to a desk or laptop computer may be the best solution.

For recording of sub-audible signals, an Analog-to-Digital converter wired to your PC may be the only solution.

In any case, with today's digital technology, there are lots of good solutions available at an affordable price. Shawn Korgan has done some hands-on testing, see his letter below.

Your Much Appreciated Correspondence

•**Shawn Korgan, Gilcrest, Colorado (shawnkorgan@juno.com)** I went to the local Wal-Mart and purchased several recorders as a test. The first was an RCA RP5012 digital tape recorder that can record up to 6 hours of audio. The current price is $48.92. It features low and high quality record settings, low and high sensitivity microphone settings, a microphone jack, earphone jack and ac adapter jack. It offers many other high tech features along with the standard features such as stop, pause, play, record, etc…

I tried the different record settings on the unit and all of them had a less than desirable sound quality upon playback (even when using the highest quality settings). The faintest sounds were somewhat garbled and there was a distinct oscillating hiss in the distant background. Sounds with a little more strength to them turned out more normal sounding while the loudest sounds were normal sounding to the ear. From this experiment, I would not select a digital tape recorder for VLF data collection work until the sound quality can be markedly improved. Other units appear to work slightly better (from previous in store tests I've done in the past) but overall, the sound quality is still lacking in these units for any type of high quality recordings.

The second unit I purchased was a Sony mini-disk recorder model MZ-N505. The price is $128.82 and is just slightly larger in size than a credit card and about ¾ inches thick. The sound quality upon playback cannot be beat! I've never heard anything sound so great in my life. Really, the sound quality is just that fantastic!

The recording level is preset to automatic level control but can be turned off (this has to be done each time a person starts recording) which then engages the manual recording control. The manual recording level is adjustable from very close to microphone level all the way to very strong line level signals. As a simple test, I turned up both the recorder's input sensitivity and volume playback controls to their maximum settings. Upon touching the input leads, instant loud 60 Hz hum is heard. Upon releasing the leads, there is nearly total silence! The recording input is so sensitive on this unit that it would easily pick up whistlers by itself if hooked to a long wire antenna! (Of course, precautions would definitely need to be taken to protect the input stage of this unit and also some filtering would be needed to eliminate out of band signals higher in frequency).

Plugging in a pair of headsets, allows a person to monitor exactly what is being recorded even when there is over modulation in the sound occurring due to too high of signal input. Upon playback, everything is heard identical to when it was being recorded.

The unit includes computer hookups, CD creation software, an AC wall adapter, a headphone jack, a pair of headphones, a USB jack, an audio line in jack, another type of computer port, and a re-recordable mini-disc that has a capacity of up to 5 hours on a single 80-minute disc. It has time stamp and many, many other features as well.

There is an onscreen record level strength meter that works exceptionally well.

The signal to noise ratio on the input of this unit appears to be vastly superior to my current setup. This may very well help to eliminate some of the remaining noise in the recorded VLF signal. From all indications, this unit is going to work just fantastic for VLF related data collection efforts!

The highest quality record setting must be used to obtain accurate playback sound. Use anything less than the highest quality record setting and the quality of the audio begins to suffer just slightly upon playback. Using the highest quality record setting allows 80 minutes of stereo recording per mini-disc (mini-discs run about $1.00 a piece and can be re-used). As a note, the lowest quality record setting on the Sony mini-disc player offers a large sound improvement over the digital RCA tape recorder in its highest quality record setting.

If a person wants to manually control the record level, this must be set each and every time before hitting the record buttons to record. By a little experimentation, I learned that the auto level control is for all purposes disabled if the audio level input is kept within the first two or three recording bars on the recording level meter. Due to this fact, manual adjustment of the recording level will be unnecessary and the ALC can be kept in the auto mode with no problems of sound reduction of the fainter background sounds following loud sound transients such as sferics. I tested this last night for a while on the home VLF receiver with strong sferics in progress.

When recording VLF audio with a tape recorder, I have the habit of constantly rewinding the tape and recording over portions with no activity every few minutes. This can also be done with mini-disc recorders, although it is a much more time consuming process and a person would likely just want to keep the recorder rolling and edit the recording at a later time.

One final comment, the audio recorded onto the mini-disc player cannot be digitally transferred to a personal computer. The only way to transfer sound off of the mini-disc player is through the headphone output jack which then must feed into the sound input of the computer's sound card.

I hope these comments have been helpful for those considering using something other than an analog tape recorder.