The Sonocent guide to ***recording devices***

Introduction

What is the best way of recording lectures?

In the past, a specialised recorder – first of all cassette, then minidisk, then digital recorder – was the only way to take a reasonable recording. But in recent years PCs, phones and, latterly, tablets have been equipped with quality microphones and now offer a viable alternative.

Many DSA assessors and Sonocent Audio Notetaker users ask us whether, in light of these advances, there is still significant difference in the standard of recordings taken with different recording devices.

So, as audio experts with decades of experience in this area, we thought it time we did some proper tests to find out exactly how much variation in sound quality there is between devices, and what can be done to take the best recording possible.

This guide is the result of our investigations. Its purpose is to equip you with all the information you will need when advising students how best to take recordings of their lectures.

If you have any questions about the guide or our findings, please don't hesitate to get in touch by visiting www.sonocent.com/dsa or contacting support@sonocent.com.

Best wishes,

Roger Tucker
Founder and CEO, Sonocent

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Section 1 – Summary

Our conclusion

The conclusion may seem an unusual place to start this guide, but the results of our tests surprised us, and are worth sharing first.

In a nutshell, we found there to be **little difference** in raw audio quality between the devices tested. It didn't matter if it was an iPhone or a top-of-the-range digital voice recorder (DVR) equipped with an external microphone; intelligibility was comparable between all recording options *(*listen to our summary examples and judge for yourself*)*.

On the other hand, *there was a difference* in the level of **interference** from device to device. That is, external sounds which can make it difficult to understand recorded speech. Each device had its own susceptibilities, and some can be negated by taking some simple measures. We give our recommendations for achieving optimum recording quality, and minimising the effects of interference, throughout this guide and have also included a 'Recording Tips' section at the end for students.

We also briefly surveyed the native recording quality of a range of Android devices. As with recordings taken with laptops, quality varied enormously. The better ones were as effective as our test devices, the poorest ones were very bad.

See Appendix 1 for full details of the devices tested.

Our main test devices were:

- iPhone 4 using 'Sonocent Recorder'
- iPad/iPad mini using 'Sonocent Recorder'
- Olympus DM670
- Philips DVT6000
- Olympus DM670 with Olympus ME32 external analogue microphone

For the second tests (see next section), we also tested:

- Samson Go external (digital) microphone, plugged into a laptop
- Kindle Fire HDX using 'Simple Recording App'

Prior to releasing this report, we also performed informal tests on the very latest Olympus DVRs, the DM901 and DM7, and a range of Android devices. The Olympus DVRs performed as well as the DM670 tested, and were better in the respect that they do not have the same susceptibility to mobile interference – *see section 3.1.* The Android results were a different story – *see section 4.4.*

Our tests

In the first of our tests, we made live recordings in average-sized lecture theatres (approx 200 seats) of two lecturers who had both chosen not to use the PA system. We sat in the back row each time, to give a worst-case scenario, and recorded on all the main devices. Both lectures were well attended with well over 50% occupancy of the seating. While one lecturer projected reasonably well, the other spoke very quietly. This was the *very worst-case scenario* for recording a lecture – a quiet speaker, no PA, sitting at the back with lots of other people – and a very tough test for any recording device.

In the second tests, we played a lecture that had previously been recorded using a headset microphone through the PA system of two lecture rooms, one large lecture room (seating around 400) with good acoustics and one small room with poor acoustics (seating around 40). The repeatability of the environment meant that we could record as many different conditions as we liked, and we added a laptop, with an external Samson Go digital microphone, and a Kindle Fire HDX with a recording app to the array of devices tested. There were no people in the two rooms during the recording, except for the two people making the recordings.

In the informal tests of new DVRs and Android phones, we played a recording quietly from a laptop at 2m and 5m, and recorded it using the test devices alongside one or more of our main test devices. We were then able to judge how well the new devices performed compared to our main test devices, both by listening and by carefully observing spectrograms of the recordings.

Using Sonocent software with audio devices

Although this guide has been written to answer the question of how audio quality varies between devices, it is important to remember that the decision on which device to use will primarily depend on how the student wants to take their notes, their needs and the available budget.

In general, simply having access to an audio recording is only one step along the road to effective note taking, either for study or as a form of accommodation for a disability. Listening back to a long recording without actively engaging with the content is time consuming and, studies indicate, of little benefit. Using recordings as part of a study strategy which involves active listening, summarising and review is likely to be of far greater value.

Sonocent's note-taking software supports recording on PC, Mac, phone, tablet or digital recorder through our products Audio Notetaker (PC/Mac) and Sonocent recorder (iPhone/iPad). The software offers a wide choice of annotation features - sectioning, colouring, typing and pictures - as well as a visual display of the audio recording.

Our approach to note taking allows students to colour-code parts of their lecture recording before revisiting this material to take notes in their own time. This process is simplest and most efficient when the student can annotate as they go, for which they will need a PC or mobile/tablet.

Audio post-processing

It is also important to note that the audio recording quality delivered by most devices can be improved by playing the recording through audio software such as Audio Notetaker itself.

Audio Notetaker features various post-processing playback options: noise cancellation (from v3), automatic volume control, key-click suppression, rumble removal. This helps make all recordings usable, whatever recording device was initially deployed.

However, for the purpose of our comparison, the only feature that we used when testing Audio Notetaker was volume adjustment, after which the speech level from all the devices was approximately the same.

Section 2- What makes for a good recording?

Sound Level

If you listen back to a recording and the speech is quiet, it is natural to assume that the recording quality was poor. However, sound volume and audio quality are not the same. Speech from some recording devices sounds louder because these devices include Automatic Gain Control which dynamically adjusts the volume of the recording. However, volume differences are easily corrected and Audio Notetaker (v4) will do this automatically when recordings are imported.

During our tests we found a large variation in the sound level of the recordings taken. All the devices offered automatic recording level setting, but this seemed to work to different degrees of effectiveness, with the Apple devices producing the quietest audio and the Olympus devices the loudest. However, once the recordings were imported into Audio Notetaker (v4) these differences disappeared.

Conclusion:
There is a large variation in sound levels between recordings taken with different devices, but these variations can be simply and effectively removed with audio software such as Audio Notetaker *(*sound example 1 *&* sound example 2*).*

Intelligibility

The key criterion for assessing recording quality is whether, when listening back to a recording, you understand what was said.

Overall, the tests showed a surprising consistency in quality between all the devices in terms of their raw recording intelligibility, although other problems did emerge, mostly due to **interference** (see the next section). Almost all the recorded speech was intelligible *on all* the devices, even when the lecturer spoke very quietly. So it is only in a very few places of the recordings that it is possible to rank intelligibility.

When recording the audio played through a PA system (i.e. through speakers in the lecture hall), recordings from *all* devices were equally intelligible.

In the quieter of the two live lecture recordings there were a *few* places where it was possible to rank devices on the basis of intelligibility (excluding those instances cause by mechanical or electrical issues – more of which below). In these places, recordings taken with the iPhone/iPad were slightly less intelligible than the two DVRs, which in turn were slightly less intelligible than the DVR with an external microphone, but the differences were marginal. We have provided you with two examples of these instances so you can decide for yourself *(*sound example 3 *&* sound example 4*).*

There is a more technical way in which we can assess the relative intelligibility of the recordings, and this can be applied to new recordings without needing to record an actual lecture. Please see Appendix 2 if you're interested. This method corroborates the above results.

Conclusion:
Although there was minor variation between devices, almost all the recorded speech was intelligible on *all the devices.* The biggest factor affecting intelligibility is whether there is interference. Some interference is preventable, which means that it is possible to optimise recording quality regardless of which device you use.

Sound colour

Although all the recordings offered very similar intelligibility, the timbre or "colour" of the sound (i.e. its spectral characteristics) produced by each device did differ *(*sound example 2 *&* sound example 5*).* While, with one recorder, the sound changed depending whether you selected "dictation" or "lecture" mode *(*sound example 6*).*

When listening to our audio examples, you will notice that it is the ambient noise that is most noticeably different for each device, rather than the speech. It varies from hissy (Kindle Fire HDX) right down to rumbly (some DVRs). But this does not affect the intelligibility of the speech, since in the important frequency range for speech (300-3400Hz), the noise is actually very *similar* between devices.

If listening to music, this variation could be significant. With speech, however, you quickly adjust to the sound colour and after a short while you no longer notice it. (This effect is comparable to the experience of attending an amateur film showing where, at first, the sound is very muffled, but after a while you adjust and it becomes perfectly clear. Or when you talk on the telephone and at first the person's voice sounds different to when you communicate face to face, but after a while it sounds quite normal.)

How you rank the various sound colours depends very much on personal taste. In any case, the sound can usually be adjusted using the playback program – For instance, Audio Notetaker allows the removal of low-frequency "rumble" sounds, while you can use the software's noise cancellation feature to reduce *all* the noise, which makes for a more enjoyable listening experience.

Conclusion:
Sound colour varies from device to device and the type that you prefer is largely matter of personal preference. Moreover, listeners quickly adapt to sound colours to a point where they no longer notice them.

Audio format and compression rate

All Sonocent products record by default at 32 kbits per second, which equates to 14.4MB per hour. For the types of recordings made for the purpose of note taking, this is of more than sufficient quality and has the advantage that the disk space on the recording device will not fill up too quickly.

How have we reached this conclusion?

Well, the technical explanation is that audio can either be recorded uncompressed (PCM), in which case it is usually found in a WAV format file, or compressed using one of a number of common audio compression standards – MP3, M4A/MP4, Opus - or proprietary formats such as WMA or DSS. All these formats reduce the file size. Most have different settings so you can choose the level of compression you want, which is usually measured in kbits per second or Mbytes per hour. PCM is around 1411 kbps (635 Mbytes/hour), and most compression schemes offer rates from 8 to 192 kbits/sec (3.6 to 86.4 Mbytes/hour).

Using audio compression makes the audio very much smaller, but does it affect the quality? It depends what you are listening to and why you are listening. For example, if you are recording an unaccompanied choir, you need the best quality possible, since not only is the sound itself complex and subtle, but your listeners are listening for the pleasure of the beautiful sound produced. But if you are recording a lecture, any subtlety in the voice has already been lost because of the distance you are recording at, and in any case you are listening to what is being said, not the beautiful sound of the lecturer's voice.

Don't assume that because the recording quality is already degraded by ambient noise you will need the best possible quality setting on your recording device. If anything, the opposite is true – the ambient noise will tend to mask any subtle artifacts of the compression scheme.

However, as the compression setting gets more and more severe, the artifacts do become noticeable, and you have to trade off file size with audio quality. For lecture recordings, this tradeoff will occur in the 16-64 kbits/sec region, depending on the recording format and the quality you want.

Audio Notetaker and Sonocent Recorder both record in the Opus format, the most recent of all audio standards and the one which offers best quality compression. *(*Listen to the sound file examples *provided - recoded into high-rate m4a so you don't need an Opus decoder to hear them - and see if you notice any difference above 32kbits/sec).*

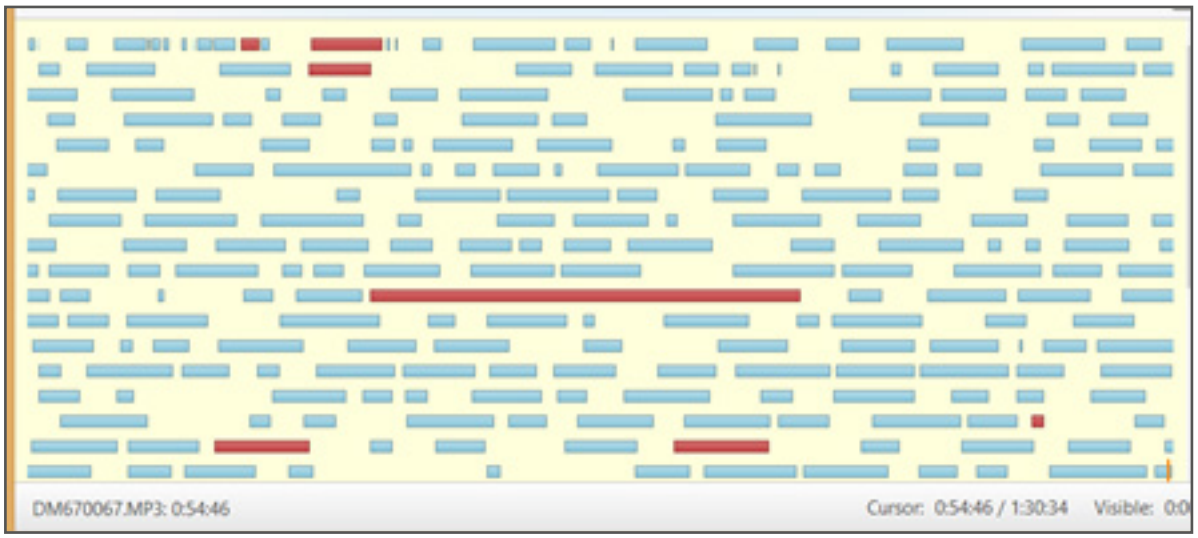
Section 3 - What makes for a bad recording?

There were a number of types of interference which, when they occurred, affected the intelligibility of the recordings significantly:

Mobile phone interference

We are all familiar with the Morse-code-like interference that you sometimes experience when your phone is too near a microphone, cable or PA system. Whether or not your recording will suffer depends on how far you are from the base-station (your phone adjusts its transmit power accordingly) and, of course, how far your phone is from the recorder. But it also depends on the susceptibility of the recording device itself.

The iPhone that we tested occasionally experienced a minor level of interference from its own transmission. Although audible as a quiet ticking sound, the speaker could still be heard clearly and so it did not affect the intelligibility of the recording *(*sound example 7*)*. By contrast, the Samson Go digital microphone and the Olympus DM670 both picked up the iPhone's transmission very severely (the iPhone was 30cm distant), rendering the recording unusable in places *(*sound example 7*)*, but, fortunately, not very often:



Mobile interference (in red) over 55 minutes. Each line represents 3 minutes.

However, with forethought, it is possible to mitigate the impact of mobile interference. For example, with the Olympus DM-670 we found that there was no mobile interference when the ME32 external mic was plugged in to the recorder. No problems with mobile interference were encountered with the other brand of recorder (Philips), the iPad, or the new Olympus DVRs (DM7 and DM901).

Bangs from the recording surface

We found a susceptibility to mechanically-transmitted interference through the desk that the device was placed on, which in our lecture rooms was a desk shared by the whole row (for example someone kicking the desk or a seat in the row in front banging the desk). The iPhone/iPad seemed particularly susceptible, digital recorders less so and an external mic the least. These effects were reduced by putting the device on something which dampened the vibrations through the desk, such as a soft case designed to angle the device. One of the recorders had a flip-down stand which seemed to help a lot *(*sound example 8*).* Most of the adverse impact on the iPhone/iPad was due to the automatic recording level system dropping the level when a "bang" occurs, and then taking a short while to ramp it up again so that the speaker was very quiet for a few seconds *(*sound example 9*)* but, fortunately, this did not occur often.

Extraneous sounds – coughs, talking, movement

The effect of extraneious sounds would be minimised by sitting as close as possible to the lecturer or the PA speakers (if the PA is on), but in our tests we maximised them by sitting on the back row. We expected the "zoom" directionality of the digital recorders (particularly with an external microphone) to help reduce these effects compared to the phone/tablet, but in practice there were so many reflective surfaces around us (particularly the desk itself) that the zoom settings seemed to make little difference *(*sound example 10 *&* sound example 11*)*

Although recording near the front minimised these sounds, a word of warning is needed: we did try placing the recorder on the podium at the front of the seminar room and found that the projector (which came down from the ceiling in the same place) added a little bit of fan noise to the recording. No problem in our case, but it is always worth being aware of noise sources near the recorder, even at the front.

Key Clicks

A particular problem with recording on a laptop without an external microphone is the distraction caused by the background sound of key clicks from typing *(*sound example 12a*).* In our experience, key/mouse clicks are particularly pronounced when the internal laptop microphone is positioned on the lower half of the laptop (as it was in the sound example above), but are minimised when the internal microphone is at the top of the screen.

With an external microphone, however, the problem of key clicks is much reduced *(*sound example 12a*).* In our tests, we had the Samson Go microphone clipped to the screen (which is how it is designed to be used), but the key clicks would have been further reduced if it had been placed on the desk.

You can also reduce the prominence of the clicks by typing slowly and gently - it is typing at touch-type speed that really does the damage!

Audio Notetaker v4 offers key-click suppression on playback. This makes the key clicks much less intrusive *(*sound example 12b*).*

Section 4 - Recommendations

Tips

If you pay £5 for a recorder on the internet, you should not expect a good quality recording. However, the recording devices that we used, each of which were manufactured by reputable brands, all offered a reasonable recording. Any differences in the quality of sound paled into insignificance compared to interference problems which can be minimised by following the simple tips below:

- Put your phone on “airplane” mode, particularly if you are recording with it. This will also help with battery life! or with a digital recorder or external digital microphone that is susceptible to mobile noise. If you are using a digital recorder which is susceptible (Olympus DM670 or Samson Go), consider using an external Olympus ME32 microphone if the noise turns out to be a problem.
- Don’t place your recorder directly on the desk, place it on something soft which will absorb vibrations and reflected sounds from the desk.
- If using an iPhone or iPad, using a case which can prop it up at an angle will help limit mechanical noise.
- Sit reasonably near the lecturer or PA system.
- If the recorder is too near a projector, you may lose some of the advantage of having the microphone close to the lecturer due to the fan noise.

Noise Cancellation

Some devices and recording programs offer noise cancellation during recording. A PC’s internal microphone usually has this on by default and it takes quite a lot of burrowing in settings menus to find where to turn it off [1]. It is better to record with it off as it can be applied afterwards (in Audio Notetaker for example), but if you record with it on you have no option to listen without it. While noise cancellation makes for easier listening, if the voice is borderline unintelligible, you have the most hope of hearing what was said with noise cancellation off.

University Recordings

If you are able to persuade them, an almost ideal option is for the lecturer to wear a tie-clip or headset microphone. This will give the best quality possible for the lecturer’s speech and is the recommended solution when quality really matters – for instance, if the recording is for a general audience and not just for you.

There are some drawbacks though. Questions/comments from the lecture theatre itself do not come through well, if at all. Depending on the class, this can be a significant disadvantage of centralised recording, which can only be overcome by a second recording device and some careful audio editing.

[1] Playback Devices > Speakers > Properties > Enhancements

Centralised recording also makes it harder for students to tie the notes they take *during* the lecture with the recording they get *afterwards*. If they rely totally on the recording, listening becomes a passive process, both during the lecture and after. Research shows that active participation in a lecture (even just pressing a button when you think its an important point) helps students recall the information at a later date.

In order for students to use centralized recordings and annotate their lectures as they listen, we are adding an 'Audio Replace' feature to Audio Notetaker v4 so that users can simply replace the audio recording made on their laptop or mobile device with one provided by the university. Audio Notetaker will automatically transfer all annotations and notes, along with any extra audio, from the old recording to the new recording.

Android

The Sonocent Recorder app will be available for Android early 2015, so the quality of audio captured with Android devices is a pertinent issue.

Over the years, we have discovered a wide variation in the quality of the internal microphones in laptops, and we expected to find a similar variety amongst Android devices. We were not disappointed. We informally tested 3 Android devices – the Kindle Fire HDX, the Sony Xperia SP and the Google Nexus 5. The Kindle Fire HDX, although a little bit hissy (i.e. noisy at high frequencies), is similar in quality to the other of our main test devices. The Sony Xperia SP is noticeably (about 3dB) noisier and would not have performed well at the back of the quiet lecture, but would have been fine for the other lectures. It was however very much better than the Nexus 5, which gave terrible audio quality, and could only be used for recording close-up *(*sound example 13*)*.

With laptops, the advice we have always given is to have an external USB microphone like the Samson Go available. Not all laptops in all recording situations will need it, but it ensures a reasonable quality of recording is always possible. With Android, this has not been an option until recently with the release of 5.0 (Lollipop), where it is now possible to plug in an external USB microphone, providing that the phone's hardware supports USB audio input. We tried this on our Nexus 5 with a Samson Go and cheap OTG connector cable, and it worked very well. However, it did double battery life during recording – from 6% to 13% for a 55 minute recording.

An alternative to a USB microphone is to use Audio Notetaker 4's 'Audio Replace' facility, which allows users to replace a bad recording with a good one. The good one could either be the university's own recording if one is available, or one taken by a student with a separate DVR, which could be an entry level device placed at the front of the lecture.

Note: we do not recommend a Bluetooth microphone for Android as Sonocent Recorder will not support recording from Bluetooth, and in any case we have not yet found a Bluetooth microphone of sufficient quality to record a lecture.

Section 5 - Device guide

Device	Positives	Negatives
Laptop	Good if you want to type lots of textual notes to go with the recording	Recording quality varies between brands and even within brands, so you can never be quite sure how good it will be if you can't try before you buy
	No extra purchase needed (assuming you already have one)	Quite large to carry around
		Need to be careful with key clicks affecting audio quality
		Battery may not last if you want to record all day away from a power plug
...with external microphone	Reliable recording quality	One more thing to setup and to lose/forget
	Reduces key click issue	Samson Go susceptible to mobile noise
iPad/iPad Mini	Good battery life	Onscreen keyboard not as easy to type on as a laptop (although many external keyboards are available)
	Portable, though you still have to think ahead to bring it	
	Reliable recording quality	
iPhone	Don't need to plan in advance – already have it	Battery may run low if recording all day, especially for older phone (use airplane mode to minimize battery drain)
	Don't need to buy an extra piece of hardware	You need to ensure you have enough space on your phone for your recordings
	Reliable recording quality	
Android devices	These have the same advantages as iPad/iPhone but the drawback of the laptop – recording quality is an unknown until you try it. New devices may support an external USB Microphone.	
Digital voice recorder	Excellent battery life	Can't take live notes on the device
	Reliable recording quality	Another device to remember to take with you
		Additional cost when you probably already own a device that can record audio
...with external microphone	Best possible recording quality	One more thing to carry/keep/setup
	Avoids mobile interference if recorder is susceptible to it	

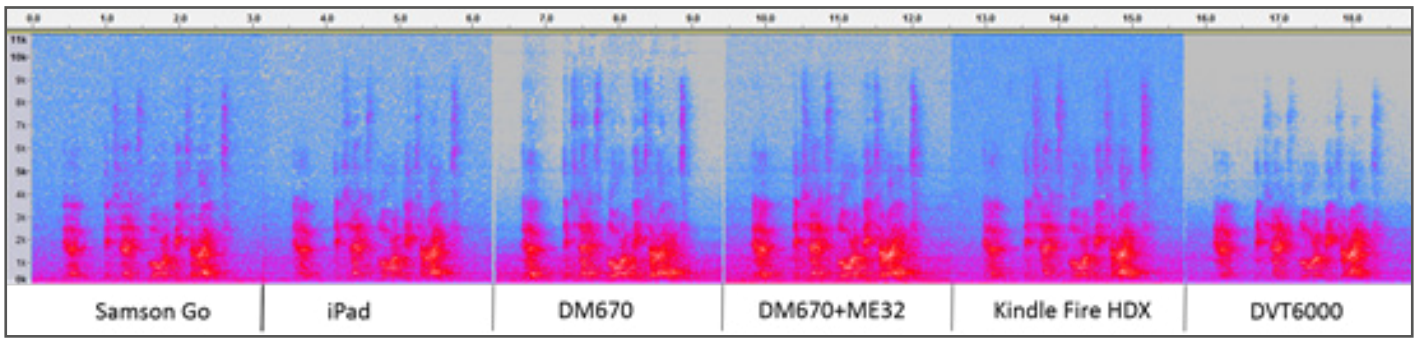
Appendix 1 - Recording devices tested

Device	Model	External Microphone	Microphone setting	App	Live test	PA test
Phone	Apple iPhone			Sonocent Recorder	X	
Tablet	Apple iPad/ iPad Mini			Sonocent Recorder	X	X
DVR	Olympus DM670		Maximum zoom; low cut (live test only)		X	X
DVR	Olympus DM670	Olympus ME32			X	X
DVR	Philips DVT6000		Long distance		X	X
DVR	Philips DVT6000	Olympus ME32				X
Laptop	Toshiba Satellite Z930-10X		Default	Audio Notetaker		X
Laptop	Toshiba Satellite Z930-10X	Samson Go (digital)	Directional	Audio Notetaker		X
Tablet	Kindle Fire			Simple Voice Recorder		X
Phone	Sony Xperia SP			Sonocent Recorder (prototype)		
Phone	Google Nexus 5			Sonocent Recorder (prototype)		
DVR	Olympus DM901		Maximum zoom			
DVR	Olympus DM7					

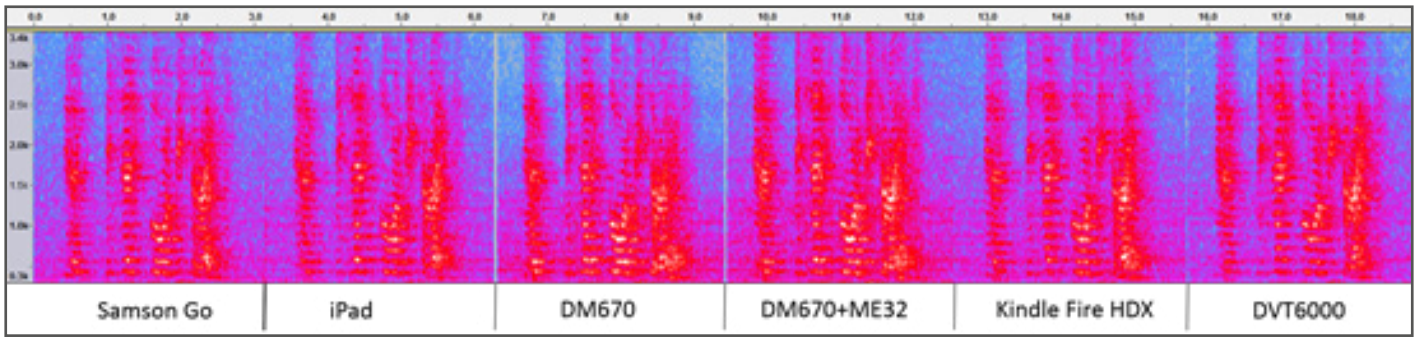
Appendix 2 – Spectrogram Analysis

Intelligibility is determined primarily by the amount of background noise obscuring the speech signal you want to hear, so a very good guide to intelligibility is the amount of noise compared to the speech signal. When listening to the background noise in the recordings *(listen to* sound sample 2 again*)*, you are at first aware that some have low frequency noise (rumble) and others have high frequency noise (hiss). But neither of these necessarily make the speech less intelligible. What matters most is the amount of noise in the main speech frequency band of 300-3400 Hz. This is the frequency band that is used for telephony, and it contains most of the speech information. When the recordings are filtered to this frequency range *(*sound example 14*)*, you can hear that the variations between devices becomes very much less.

A useful alternative to listening is to look at the **spectrogram** of the speech. This is a plot of signal strength (indicated by colour) with frequency on the vertical axis and time on the horizontal axis. Here is the spectrogram for example 2:



And here is just the 300-3400 part of the spectrogram:



You can see that whereas there is a lot of difference in the amount of noise over the whole spectrum (the blue background), in the crucial range 300-3400 there is very little difference.

However, having said all that, the frequency range above 3400HZ does add some intelligibility – think how hard it so to distinguish between “f” and “s” on the telephone and how many times you end up saying “foxtrot” and “sierra”. And so from the top plot you can see that for the DVRs the lower noise level will make these kinds of sounds more distinguishable, and it is this that gives them the slight edge on intelligibility. Although the DM670 has a better high-frequency response than the DVT6000, we did not think this made any difference to intelligibility in any of our recordings, but it did make for a “brighter” sound.