Two Next Generation 950 MHz STLs –
Digital Composite and Linear 24-bit AES/EBU

Composite STLs, Then and Now

It wasn’t so long ago that station engineers had one choice for carrying audio program from their production studio to the transmitter site. They used equalized analog landlines leased from the telephone companies. Though an adequate solution for monaural transmission its limitations became more prominent with the advent of stereo transmission. Several lines were required for one channel and composite transmission was out of the question. In the mid 1960’s, Moseley Associates introduced the first composite microwave STL for stereo transmission, the PCL-303C. This radio link provided a single wideband channel for transmission of the broadcast composite stereo signal.

The composite STL provided a cost effective alternative to the fixed recurring expense of leased analog lines. It also unburdened the broadcaster from other annoyances associated with landlines such as frequent maintenance issues, reliance on the telephone company, installation costs and right-of-way issues. The composite STL had other useful benefits as well. It allowed the audio processing and stereo generation to be placed in the studio that in turn allowed convenient “tweaking” or tuning for the optimal studio sound. The composite STL also provided the ability to drop a feed of the station’s composite transmission at repeat sites without the need for stereo regeneration at each site. Following these developments audio processors began incorporating an integrated stereo generator as standard practice. Now it is rare to find a studio audio processor without a built in stereo generator, or an option for adding one.

These days digital audio dominates the scene following a boom of inexpensive digital audio products through the 1980’s. Digital audio’s superior performance and robustness have had a profound and far reaching effect on our expectations of audio quality. Hence, a mandate grew quickly for the implementation of the all-digital air-chain; getting digital audio from digital storage source to the exciter using only digital interfacing and technologies. As digital audio products implemented interface standards set forth by the AES/EBU (Audio Engineering Society/ European Broadcast Union) for connector interface, data format, and sample rate, digital audio interconnectivity became reasonably simple and reliable and the all-digital mandate was soon to be realized. By the end of the 1980’s only one link in the chain was missing, the digital studio-to-transmitter link.
Enter The Digital Studio-to-Transmitter Link

The final link in the all-digital air-chain was completed in 1990 when Moseley Associates introduced the first digital STL, the DSP 6000. The DSP 6000 was a ground-breaking product. As an add-on to an existing analog FM STL, it was able to squeeze up to 4 discrete audio channels into a single Part 74 frequency allocation. It was able to achieve the spectral efficiency to do this by using hybrid multilevel digital-FM modulation, CPFSK, and reducing the aggregate data rate by using audio data compression and digitally multiplexing of discrete audio channels (i.e., left and right) rather than of the composite signal. Four 15 kHz, 16-bit audio channels processed in this way could be transmitted at 512 kbps and fit into 500 kHz channels. The composite signal on the other hand, which could not benefit from data compression, would require a minimum of 1.792 Mbps to transmit. This data rate was far too great to fit into part 74 allocations using CPFSK modulation.

A significant 26 dB benefit in system gain was realized with this add-on and the benefits of digital transmission became apparent. Greatly improved fade margin, allowing longer paths, and eliminating repeat sites were just a few of the benefits of digital transmission. Broadcast engineers were willing to trade the convenience of transmitting a composite signal over the STL to benefit from the enhanced audio quality and system gain of the discrete digital STL.

For now, at least, the station’s audio processor/stereo generator could be placed at the transmitter site or partitioned to leave the audio processor at the studio for easy access and the stereo generator at the transmit site. There were pros and cons to both of these configurations due in part to the introduction of audio processing to the audio data compression used in the STL. Though neither solution was ideal, sound quality was still superior to the analog link and the benefit of digital radio transmission enabled many otherwise problematic and difficult paths.

The Uncompressed Linear Digital STL

Though audio data compression is an enabling technology that works well in many applications there are some applications were it is less desirable. Perceptual coding used in audio data compression may be unable to mask artifacts audible to the human ear when acting with pre- or post-processing, depending on the amount. So placing aggressive audio processing before or after audio data compression may be undesirable. “Stacking” audio data compression algorithms, where multiple data compression algorithms may be used at various places in the audio chain, such as for digital audio storage mediums, is another concern. Many articles were written on this matter when the digital STL was first introduced. It was clear that an uncompressed STL solution would be the panacea required for these applications.
It took a little time for technology to become affordable but finally in 1997 Moseley Associates introduced the first uncompressed 4-channel STL, the Starlink 9003Q, the successor to the DSP 6000. To provide data packing efficiencies necessary for uncompressed transmission of multi-channel digital audio this new digital STL incorporated Quadrature Amplitude Modulation (QAM) as well as several advanced signal processing techniques at a cost normally attributable to radios costing several times as much. Accepting both analog and digital AES/EBU audio inputs the Starlink 9003Q completed the uncompressed all-digital airchain.

Digital Discrete STL vs. Analog Composite STL

Like the DSP 6000 before it the Starlink 9003Q is a discrete audio transmission system, that is, four channels are transmitted individually with a full 16-bit resolution through the radio. The discrete channel configuration, still lacking the convenience of composite configuration, continued to realize several performance benefits over its analog composite counterpart.

Channel capacity of the digital discrete STL is significantly better than that of the analog composite radio. By virtue of digital multiplexing the discrete digital system can pack four 16-bit, 15 kHz channels sampled at 32 kHz into 2048 kbps data stream. The analog composite stereo signal isn’t as efficient. Since the composite stereo must contain both mono and stereo information, the composite signal starts with 15 kHz for the mono L+R information, but then adds overhead for a 19 kHz pilot, a 30 kHz double-sideband subcarrier with the L-R information, and 4 kHz guard bands between them. In all the composite signal occupies about 53 kHz. The equivalent digital composite signal at 16-bit resolution will also take about 2048 kbps for only the two channels, left and right.

Also, stereo separation is essentially perfect in the discrete digital STL. There are no pernicious mechanisms to generate crosstalk between left and right channels. What goes in is exactly what comes out of each channel. In the analog composite radio, because of slight amplitude and phase distortions in the wideband channel, the composite signal cannot be perfectly regenerated from its original multiplexed signal of L+R baseband and L-R subcarrier. Channel distortions have their most adverse affect on the L-R difference information that resides on the higher end of the wideband composite channel (between 23 and 53 kHz) where amplitude and group delay distortions are greatest. For a good analog composite STL separation between left and right channel
will be 55 dB typically, adequate for most broadcast applications, but will be
immeasurable on the discrete digital STL. What is the "Holy Grail" of stereo separation?
Well, currently the best digital stereo generator is capable of 70 dB stereo separation.
The best digital composite STL should at least be able to achieve this target so as to not
be the limiting link in the air chain (of course, the very best FM home receivers can
achieve between 40 and 50 dB).

Ultimately, the very best audio performance is achieved via the discrete digital audio.
That is the basic audio quality issues of dynamic range, frequency response, and
distortion are resolved through direct digital interfacing of discrete left and right audio
channels as established by the AES/EBU standard.

**The Next Generation - 24-Bit AES/EBU Digital STL**

Digital audio performance is measurably better than analog audio performance with few
exceptions. But the behavior of digital audio is governed by two physical parameters
that directly affect transmission bandwidth. These are sampling rate and sampling
resolution.

Frequency response is related to sample rate. At best it is limited to half that of the
sampling rate, referred to as the Nyquist frequency. Typically it is a bit less to account
for a real filter’s gradual attenuation cutoff. For instance, in broadcast applications
requiring 15kHz audio, a 32kHz sample rate is used. For professional mastering
applications realizing 22kHz audio, a 48kHz sample rate is used.

Dynamic range is determined by sampling resolution. Each bit of resolution corresponds
to 6.02 dB of dynamic range. The minimum goal for sampling resolution in a digital
studio chain is to have at least the same 16-bit resolution (ideally 96 dB) as that of the
Compact Disc. But during the analog-to-digital encoding stage, not all this range is
usable, say, for the vacillating, chatty voice of the on-air talent.

In an analog audio chain as the audio level reaches the top of its dynamic range the
audio may compress or over-modulate. It may just sound louder and perhaps generate
mildly objectionable distortion. When analog audio is converted to digital audio and it
exceeds the full-scale capability of the digital-to-audio converter the audio is clipped
quite ungracefully. When this happens it creates a heap of objectionable distortion. As a
result digital systems have to be operated well below this overload point to avoid
clipping, sometimes backed off 10-20 dB depending on anticipated peak excursions. It
is therefore desirable to have some headroom built into the dynamic range to avoid
clipping and still achieve CD quality performance.

Professional studio equipment for audio mastering has set the audio performance bar to
24-bits resolution and 48kHz sample rate. At this resolution the audio processor at the
end of the audio chain has the most information to work with, avoiding cascaded filter
skirts, from sample-rate converters for instance, that necessarily limit the audio
bandwidth and resolution. But more bits cost more bandwidth. And bandwidth is already
at a premium; Part 74 STL frequency allocations are fixed and crowded. A trade-off is
required to provide dynamic range.

Originally, due to the popularity of the 4-channel DSP 6000 digital STL configuration, the
greater focus was on migrating to the 4-channel linear STL. This meant minimizing
sample rate to 32kHz and resolution to 16-bits to pack in the audio and data channels .
But clearly there are times when the requirement for dynamic range outweighs the
requirement for more audio channels and data channels. Fortunately the Starlink is a versatile product.

In response Moseley developed the first 24-bit digital discrete STL. The Starlink AES/EBU 24-bit digital STL is configurable for 48kHz sample rate, 24-bit resolution over microwave STL, and for 32kHz sample rate, 24-bit resolution for T1 applications. Capable of 144 dB of dynamic range and 22kHz audio bandwidth the Starlink 24-bit digital discrete STL is the final word in digital audio quality of any STL anywhere in the world.
The Next Generation - *Digital Composite STL*

When all’s said and done the most convenient STL has always been the composite STL. The composite STL won favor over dual-mono radio links when it was first introduced for its single channel simplicity. It has been the vast overwhelming favorite in analog STLs ever since. Even with the digital revolution and availability of many digital studio components there is still a dominance of all-analog studios with their composite STLs that are operating quite well today without the benefit of digital.

Still, with all its benefits, even the best analog STL has always been the determining factor on on-air performance; establishing the signal-to-noise, stereo separation, distortion, and is susceptible to radio impairments. The analog STL is the single most critical link in the air-chain to realize improvement in both audio quality and reliability from digital radio technology. For some studios, though, the current discrete digital STLs involve too many trade-offs or too much cost.

To address these issues, in April 2002 Moseley Associates introduced the first *Digital Composite STL*. The Starlink Digital Composite STL will directly replace an existing analog composite STL and provide a significant audio quality and system gain improvement.

The Moseley Starlink Digital Composite Card and Interface

The Starlink Composite accepts an analog composite input and provides an analog composite output, both with full *16-bit sampling resolution*. Previously a 16-bit Digital Composite link was thought unattainable due to the required data throughput, at least in T1 landline applications (since T1 circuits run at 1.544 Mbps, digital composite over T1 was limited in sampling resolution to 13 bits or less). The Starlink Composite is capable is rates as high as 2432 Mbps and still easily fit into part 74 frequency allocations.

Virtually all performance barriers of the analog composite radio have been crushed. 16-bit sampling achieves a signal-to-noise ratio of >85 dB. Composite performance further exploits the advantages of digital signal processing. Utilizing near perfect amplitude-linear and phase-linear FIR digital filtering, unparalleled stereo separation > 70 dB, and distortion <0.02% are achieved. The Starlink Composite sets new audio performance standards for a composite link.

RF performance is also unsurpassed. Like its SL9003Q digital brother, the Starlink Composite benefits from true digital QAM transmission. Reed-Solomon error correction
and data interleaving, coupled with a 20 tap adaptive equalizer, allow for signal quality restoration not provided nor permitted by analog radios. The result is greatly enhanced signal robustness and error free transmission in hostile RF environments.

Most importantly, system gain is greatly increased. The Starlink Composite in its standard composite transmission mode operates to a threshold of –91 dBm or 6 uV. Compared to the analog composite counterpart this represents a system gain improvement of 20 dB. It is also important to note that audio quality is constant down to threshold as a result of the aforementioned error correction. That means that were the analog composite STL will degrade SNR as signal level drops, or adjacent or co-channel signals trespass on the desired signal, the digital composite STL will provide full dynamic range, separation, and distortion to threshold operation with no degradation.

The Digital Advantage - Digital vs. Analog Composite Threshold

The Final Word

These days radio broadcasters have a smorgasbord of options for conveying program audio from the studio to their transmitter site. Today more reliable digital T1 lease-lines and dedicated fiber optics replace the analog lines that are now rarely offered by telephone companies. To the traditional stalwart analog microwave STL have been added compressed digital discrete, linear digital discrete and linear digital composite STLs, spread spectrum STLs, and satellite links.

Generally the STL options are more varied and provide better quality and reliability. They have their good points and their not so good points but the fact remains that many of the same good reasons for utilizing microwave Studio-to-Transmitter links exist today that existed 40 years ago.

The Starlink Digital Composite STL and the Starlink 24-bit AES/EBU are the latest developments in this list of enabling technologies. The 24-bit AES/EBU STL provides the highest audio quality STL anywhere to the broadcaster that requires it. The Digital Composite STL can provide the single greatest improvement in station sound and add reliability to the most troublesome paths with the least amount of effort.