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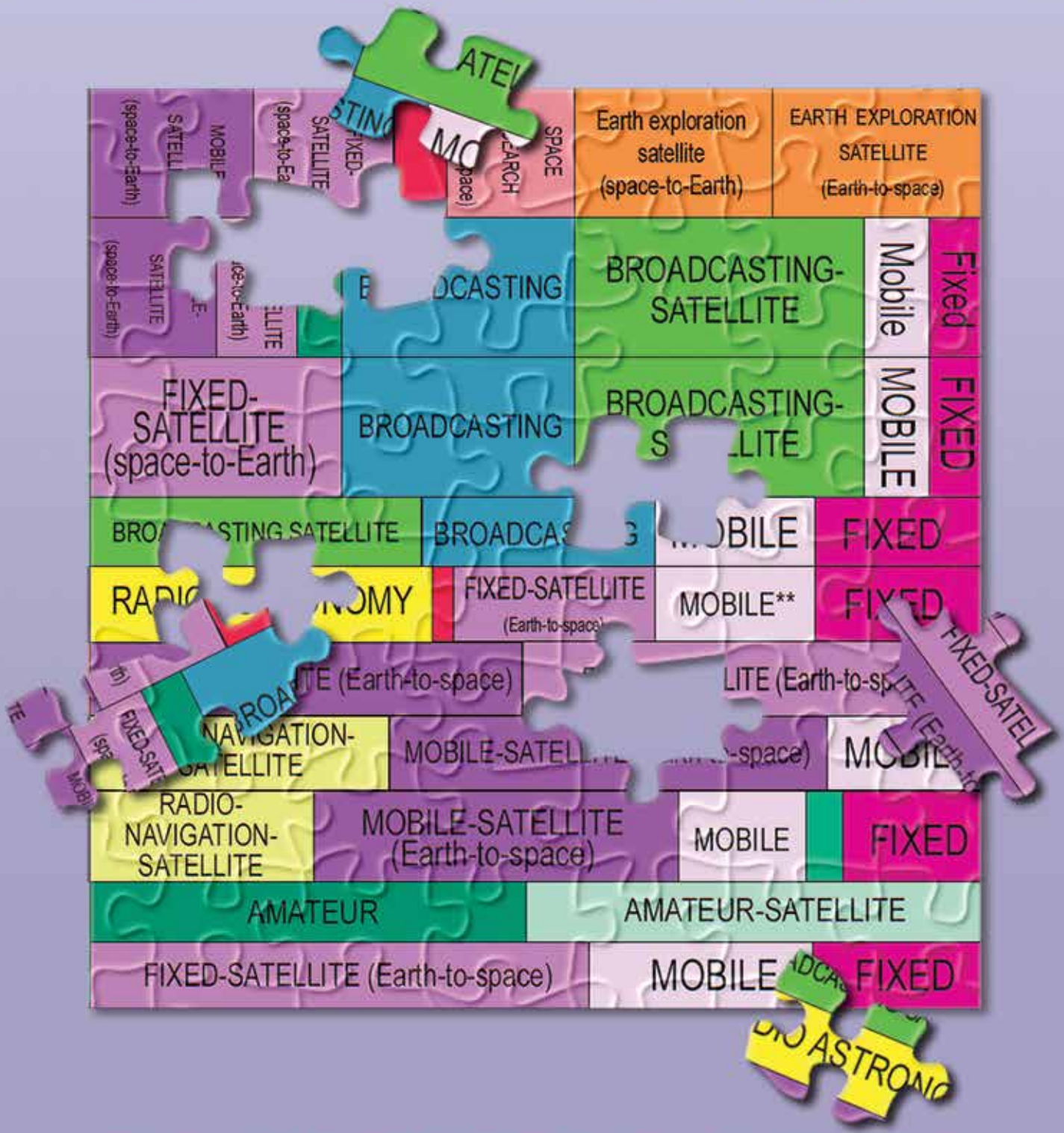
PRODUCTION SOUND & VIDEO

THE OFFICIAL PUBLICATION OF IATSE LOCAL 695



THE WIRELESS FREQUENCY PUZZLE

PRODUCTION SOUND & VIDEO

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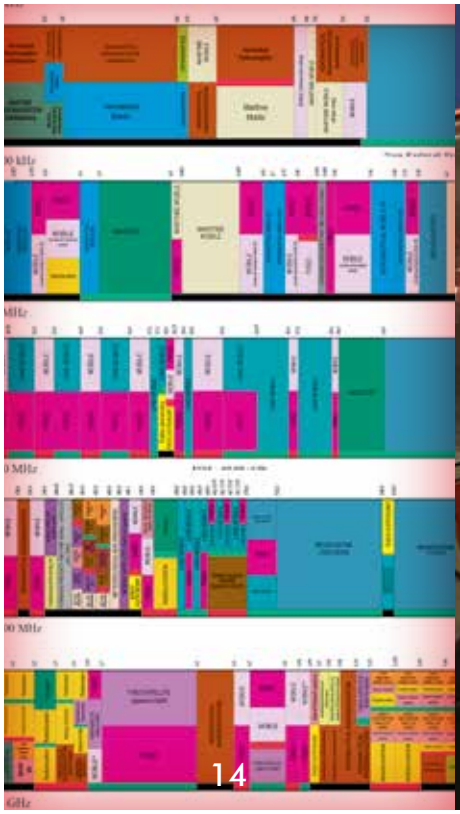

FEATURES

DEPARTMENTS

Cover: The Wireless Frequency Puzzle
Art by Laurence B. Abrams

FROM THE EDITORS

by Richard Lightstone CAS AMPS

Welcome to *Production Sound & Video,* our new name for the former *695 Quarterly*. Why the re-branding? Because we are not just a number, but also a diverse I.A. local with highly skilled engineers and creative talent.

We want the industry to recognize that we are multifaceted and brimming with technical ability, from Production Sound Mixers, Boom Operators, Sound Utility, Video Engineers, Broadcast Engineers and Studio Projectionists. That is just a broad overview of what we do.

In this edition, Bill Ruck explains "The Radio Frequency Spectrum Puzzle," Dave Bellamy discusses his design of wireless antennae arrays in "Balance Is the Word" and I interview Glenn Derry and Dan Moore in "The Evolution in Motion Capture on The Jungle Book and Beyond."

We appreciate your readership and the many fascinating articles that our members and others outside of this Local have contributed to this publication. A toast to all of you and *Production Sound & Video*!

Fraternally yours,
Eric Pierce, Richard Lightstone
and Mark Ulano


“Riveting and superbly acted”
—THE HOLLYWOOD REPORTER
A hulu ORIGINAL
THE PATH
/ OUTSTANDING DRAMA SERIES
/ OUTSTANDING SOUND MIXING
AND ALL OTHER CATEGORIES
FYChulu

FROM THE PRESIDENT

ACTION AS METAPHOR:

Well, we're drawing to a close on the great refurbishing of our Local's offices and quite a journey it has been.

At the beginning, a book of design concepts drafted for us by former Board member and Boom Operator, Patrushkha Mierzwa, nurtured preliminary creative discussions around the idea that we can embody the rebirth of this Local by taking head-on the deferred maintenance and creative design of the building.

This became a reality with the simple icebreaker of restoring a couple of our office spaces over a long weekend in the Fall. Suddenly, everything seemed possible, ideas a'poppin, great excitement afoot ...

Then, our Wizard in Residence, Laurence Abrams, achieved the impossible with the brilliant sale of our old and unneeded domain name, providing funding for the project without impacting the financial health of the Local and motivating our formation of a Building Committee, including the contributions, over time, of Peggy Names, Linda Skinner, Jeff Wexler, Jennifer Winslow, Richard Lightstone, Carrie Sheldon, Chris Howland, myself and Patrushkha Mierzwa.

As the project moved forward, Committee Chair Peggy Names and Linda Skinner made themselves available to take on the huge responsibility of organizational and creative oversight of the project. Peggy gave many hours of her time, hammer and nail and paint brush at the ready. Linda was command central, keeping the vendors, scheduling and paperwork always in order. In fact, doing everything necessary to keep things moving along for the benefit of all.

Laurence was everywhere at once, filling in whatever gaps emerged during the project.

The whole office staff really chipped in at every turn and a special thanks goes out to Scott Bernard, Laurence Abrams, Joe Aredas, Jr., Linda Skinner, Michael Kanya, Cindy Vivar and Nikki Riordan, all of whom rolled with the punches of workmen's schedules and the construction work being provided by all the vendors, subcontractors and workmen. These folks never skipped a beat in providing the first-rate daily service to our members, while frequently improvising due to the construction turmoil of their work environment. Beyond that, the staff often dove right in to help move, shift, assemble and organize whenever needed. It's a great and versatile team.

We owe all of these fine folks a debt of gratitude for the beautiful outcome. So from me, and the rest of The Members, thank you all for a job well done.

Come on down and check it out. Feel the good vibes.

Fraternally,
Mark Ulano CAS AMPS
Local 695 President

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11.22.63

/ OUTSTANDING LIMITED SERIES
/ OUTSTANDING SOUND MIXING
AND ALL OTHER CATEGORIES

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OUR CONTRIBUTORS

DAVE BELLAMY

Dave Bellamy and daughter: "I'm the one on the right and that's my lovely granddaughter, Alyssa, on the left. In 1991, at the time we opened Soundtronics in Burbank, she was not yet born. When we opened Soundtronics in Las Vegas in 1995, she still wasn't born. Today, she is thirteen years old and lovelier than ever."

BILL RUCK

Bill Ruck, a native San Franciscan, has been a Broadcast Engineer since the mid-1970s. His career includes KUSF, KJAZ, KALW, NPR-West and Susquehanna Radio for twenty-one years (KFOG, KNBR, KSAN and KTCT) as Engineering Manager. Bill is the Chair of the Northern California Frequency Coordinating Committee overseeing the use of Part 74 Broadcast Auxiliary frequencies. Mr. Ruck is a volunteer with the Maritime Radio Historical Society, a former RCA Coast Marine Station KPH, now part of Point Reyes National Seashore. Bill Ruck is the 2014 Bay Area Radio Hall of Fame inductee chosen by Chapter 40 of the Society of Broadcast Engineers. Bill poses in front of a WWII vintage PW-15 transmitter restored and in service at KPH.

RICHARD LIGHTSTONE CAS AMPS

Richard began his career in Montreal and continues to mix in Los Angeles. He is currently on the Executive Board of Local 695, a co-editor of *Production Sound & Video* and a former President of the Cinema Audio Society.

Photos courtesy of the respective contributors.

PRODUCTION SOUND & VIDEO

I.A.T.S.E. Local 695
Production Sound Technicians, Television Engineers, Video Assist Technicians and Studio Projectionists
Certified & Chartered September 15, 1930
A California Nonprofit Labor Corporation
Incorporated July 31, 1951, State of California
Affiliated with the A.F.L.-C.I.O.,
California State Federation of Labor,
and L.A. Central Labor Council

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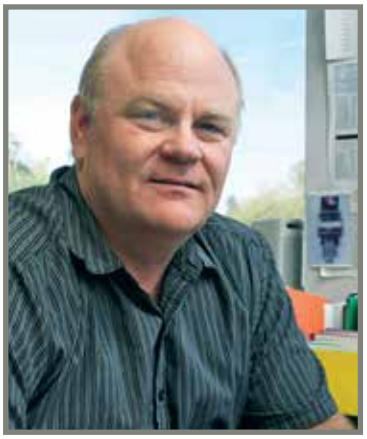
FROM THE BUSINESS REPRESENTATIVE



Welcome to the first issue with our newly branded magazine: *Production Sound & Video*. Why the name change? Local 695 continues to promote the extraordinarily diverse talents of our members but we want to be sure to remind you that we are much more than "The Sound Local." And in this issue, you'll see exactly what I'm talking about as we once again spotlight the creativity and multifaceted talents of our members. As you read this issue, you'll see that Local 695's Dan Moore and Glenn Derry's company, Video Hawks, has been inventing entirely new motion capture (Mo-cap) technology for use in Disney's incredible new film, *The Jungle Book*.

Product development moves quickly, as Mark Ulano and I saw at the NAB show, where we had a firsthand glimpse at the innovations and technology that's just around the corner. This is where the "film"-making process is headed next. These production tools and methods evolve so quickly, and so do the skills of our members who constantly amaze me with their commitment to training and developing new skills. And the Local's education department continues to update existing courses and rolls out new ones as software and hardware products evolve. The message to our members about education is unchanged: Stay active and let us know what else we can do to help.

When this administration took office in January 2015, my goal and the goal of your Board of Directors was to present to the industry the incredible skills and talents of all Local 695 members. I'm extremely proud to say it's working. When I walk onto a set, the buzz has changed. People recognize the decade's-long tradition of our Video and Sound Engineers … women and men who I contend are the most gifted and talented technical crew that you can find … partnering with producers throughout the industry to create video and audio magic on movie sets around the world.

In solidarity,
Scott Bernard
Business Representative

NEWS & ANNOUNCEMENTS

TWO VIDEO CLASSES LAST MONTH
AND MORE TO COME

"Present & Future Digital Workflows for Video Engineers"

Instructors Jillian Arnold and Tom Vanasse

Presented by Local 695 Video Engineers Jillian Arnold and Tom Vanasse, these training sessions began with a discussion about the Video Engineer's place in today's rapidly evolving production environment. Needless to say, with video now the medium of choice on nearly all film and television production, there was much to discuss.

Topics included off-camera recording, standard playback and 24-frame playback, green-screen compositing, motion capture, transcoding, backup, distribution and more.

Tom stressed that a complete understanding of digital acquisition demands operational expertise on all the major external data recorders, including those from Codex, Odyssey, Sound Devices, AJA, Atmos Systems, Cinedeck, Pronology, Grass Valley, Turbos, EVS, Blackmagic and Nexto.

The data path is critical, too, and Jillian explored the strengths and weaknesses in a wide variety of connectivity options, such as Cat5/Cat6, SAS, fiber, Thunderbolt, Expresscard34, and ultimately, IP and the cloud.

A lot of additional ground was covered in both training sessions, including storage, archiving, software, file structure, verification and industry best practices. And there were a lot of opportunities for members to share their experiences doing this work in the field and to trade suggestions and advice.

Demand for both of these classes was high and we still weren't able to accommodate everyone but for those who missed out this time, watch for announcements of more classes soon.

Local 695 Set Visits

Local 695 Field Representative Joe Aredas reports that he has logged close to sixty set visits so far this year, visiting studio lots, commercials and locations taken off the FilmL.A. database, meeting with sound and video crews at work. Joe has been partnering up with other locals, so don't be surprised to see him with other union representatives on his visits.

Field Representative Joe Aredas can be reached at (818) 985-9204 or joea@local695.com

Mark Ulano Receives Lifetime Achievement Award

The School of Visual Arts (SVA) honored Local 695 President Mark Ulano on May 10, with its Lifetime Achievement Award at its 27th Dusty Film & Animation Festival. Mark's award was presented by Chris Newman at the SVA Theater on 23rd Street in Manhattan.

Friedrichs v. California Teachers Association

On March 29, due to a 4-4 tie vote, the US Supreme Court ruled that it would not overturn the US 9th Circuit Court of Appeals rejection of Friedrichs v. California Teachers Association. The case would have overturned an earlier ruling that required public sector unions from charging a "fair use" fee for negotiating wages and working conditions, and would have the effect of severely weakening all unions by making the payment of dues optional.

Social Media & Events Committee

The Social Media & Events (SM&E) Committee has been busy with three great events!

The 3rd Annual LA Sound Mixers Winter Lunch & Mixer was held at the Bunker Hill Bar & Grill in downtown Los

SAVE THE DATE!

The next General Membership Meeting is scheduled for 10 AM on Saturday, July 16, at the Local 80 stage, 2520 W. Olive Avenue in Burbank.

Post CAS gathering at the Bunker Hill Bar & Grill

Angeles, right across the street from the Biltmore Hotel where the Cinema Audio Society awards were held the previous night. More than a hundred people crowded into the restaurant for food, drink and networking.

On Saturday, March 5, the SM&E Committee teamed up with Trew Audio for the LA Sound Mixers Flea Market. Over 140 folks came by from noon to 3 PM to buy lots of used gear from 20+ sellers. Refreshments, hamburgers and hot dogs were served.

Wildfire/Sonic Magic Studios was the site for the "Bridging the Gap Between Production & Post" seminar on Sunday, April 17. The day began with food and refreshments in the lobby provided by the Audio Department, and from there everyone moved to the mix stage for the seminar. Topics covered were dialogue editing techniques, noise reduction and the differences between mixing for feature releases as opposed to TV broadcast. Participants were able to gain significant insight as to how some of our daily practices as Production Mixers affect the Post Mixers workflow.

"Bridging the Gap Between Production & Post" seminar

LOCAL 695 SALUTES THE AMPS, BAFTA, CAS AND OSCAR WINNERS AND THEIR PRODUCTION SOUND TEAMS

AMPS AWARD

The Association of Motion Picture Sound Award for "Excellence in Sound for a Feature Film" was presented on February 8 to:

The Martian
Mac Ruth CAS, Oliver Tarney AMPS, Paul Massey
Production Sound Team: Sam Stella, Bal Varga, György Mihályi, György Mohai, Tamás Székely, György Rajna, Attila Kohári, Bence Németh, Áron Havasi

BAFTA AWARD

The EE British Academy Film Awards ceremony was held on February 14 at the Royal Opera House in London, England. The BAFTA Sound Award went to:

The Revenant
Chris Duesterdiek, Lon Bender, Martin Hernandez, Frank A. Montaño, Jon Taylor CAS, Randy Thom CAS
Production Sound Team: Charles O'Shea, Candice Todesco, **Jose Antonio Garcia, Jonathan Fuh, Alex Altman**

From left: Lon Bender, Chris Duesterdiek, Martin Hernandez, Jon Taylor CAS, Randy Thom CAS (Photo: BAFTA/Richard Kendal)

CINEMA AUDIO SOCIETY AWARDS

The 52nd Annual CAS Awards ceremony was held on February 20 at the Crystal Ballroom of the Millennium Biltmore Hotel in Los Angeles, California. The six winners were:

MOTION PICTURES – LIVE ACTION

The Revenant
Chris Duesterdiek, Jon Taylor CAS, Frank A. Montaño, Randy Thom CAS, Conrad Hensel, Michael Miller CAS, Geordy Sincavage
Production Sound Team: Charles O'Shea, Candice Todesco, **Jose Antonio Garcia, Jonathan Fuh, Alex Altman**

From left: Geordy Sincavage, Candice Todesco, Jon Taylor CAS, Randy Thom CAS, Chris Duesterdiek and Charlie O'Shea (Photo: Ana Gibert)

Candice Todesco (Sound Utility), Chris Duesterdiek and Charlie O'Shea (Boom Operator) (Photo: Ana Gibert)

Names in **Bold** are Local 695 members

MOTION PICTURES – ANIMATED

Inside Out
Doc Kane, Tom Johnson, Michael Semanick, Joel Iwataki, Mary Jo Lang CAS

From left: Presenter Onnalee Blank CAS, Michael Semanick, Doc Kane, Mary Jo Lang CAS, Tom Johnson, Joel Iwataki and presenter Walton Goggins (Photo: Ana Gibert)

TELEVISION MOVIE AND MINI-SERIES

Fargo Season 2, Episode 5
Michael Playfair CAS, Kirk Lynds, Martin Lee
Production Sound Team: Robert "Arjay" Joly, Valerie Siu, Mike Markiw, David Brown

Presenter Carlos Alazraqui, Michael Playfair CAS, Martin Lee, Kirk Lynds and presenter Mary Jo Lang CAS (Photo: Ana Gibert)

TELEVISION SERIES – ONE HOUR

Game of Thrones "Hardhome"
Ronan Hill CAS, Richard Dyer CAS, Onnalee Blank CAS, Mathew Waters CAS, Brett Voss CAS
Production Sound Team: Simon Kerr, Jonny Waite, Daniel McCabe, Bradley Kendrick, Kelly Stewart

From left: Presenter Steve Venezia CAS, Brett Voss CAS, Onnalee Blank CAS, Mathew Waters CAS and presenter Dana Gourrier (Photo: Ana Gibert)

TELEVISION SERIES – HALF-HOUR

Modern Family "Connection Lost"
Stephen A. Tibbo CAS, Dean Okrand CAS, Brian R. Harman CAS, David Michael Torres
Production Sound Team: Srdjan Popovic, William Munroe, Peter Hansen, Ken Strain, Corey Woods, Jon Sheridan, John Hays, Noel Espinosa, Brian Wittle, Devendra Cleary CAS, Steven Morrow CAS

Left to right: Presenters Phillip Palmer and Mo Collins, Penny Coghlan (Supervising Sound Editor), David Michael Torres, Brian R. Harman CAS, Dean Okrand CAS, Srdjan "Serge" Popovic (Boom Operator), Stephen A. Tibbo CAS and William Munroe (Second Boom Operator) (Photo: Ana Gibert)

TELEVISION NON-FICTION, VARIETY, MUSIC SERIES OR SPECIALS

Live From Lincoln Center "Danny Elfman's Music From the Films of Tim Burton"
Ken Hahn CAS, Paul Bevan
Production Sound Team: Lucas "Rlco" Corrubia, Kristyn R. Smith, Brian Buno, Bill Pierce, Matt Israel

OSCARS

The 88th Academy Award ceremony was held on February 28 at the Dolby Theater in Hollywood, California. The Oscar for "Best Sound Mixing" went to:

Mad Max: Fury Road
Ben Osmo, Chris Jenkins, Gregg Rudloff
Production Sound Team: Mark J. Wasiutak, Brendan John Allen, Oliver Machin, Thabo Singheni, Derek Manvelt, Ian Arrow, Sam Sergi, Mathew Ndara, Shanti Burne, Paradox Delilah, Gareth Evans, Sam Davies

Chris Jenkins (center), Gregg Rudloff (left) and Ben Osmo (Photo: OSCARS/Scott Diussa)

THE RADIO FREQUENCY SPECTRUM PUZZLE

PART 1

by Bill Ruck, San Francisco Broadcast Engineer

In order to understand what is happening with the UHF television band and how it has an impact on the use of this band for wireless microphones, one needs to take a look at several different aspects of the situation.

THE RADIO FREQUENCY SPECTRUM

The Radio Frequency (RF) spectrum is generally considered the band of electromagnetic energy from 3 KHz to 300 GHz. For the first forty years or so, only the lower frequencies were considered useful, and frequencies above about 30 Mc/s (the older term "Megacycles per second") were considered "useless." However, developments in the 1930s and especially the technology developed during World War II, expanded the useful spectrum through the microwave frequencies. By about 1970, almost the entire radio frequency spectrum was allocated to some use.

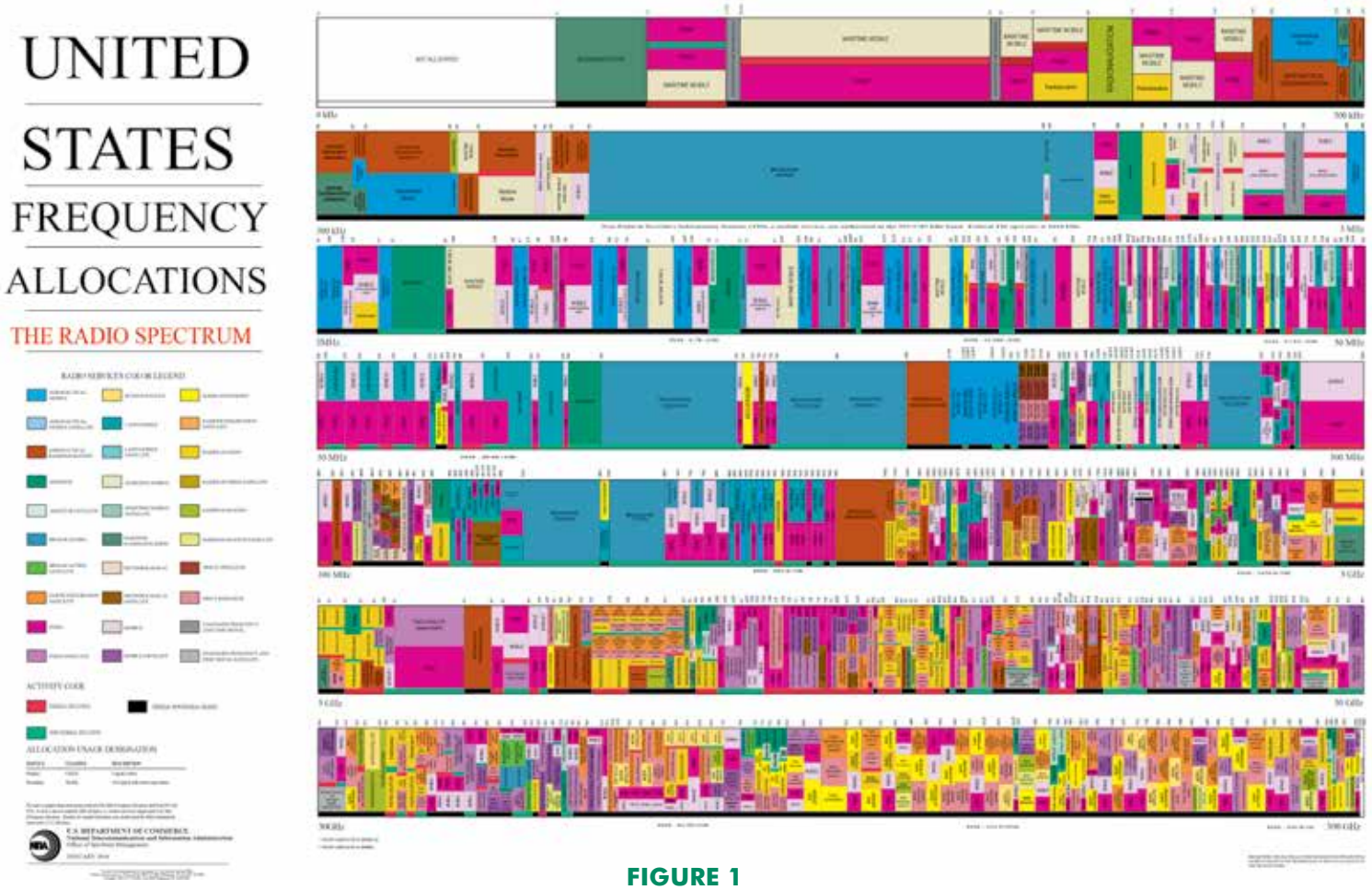


FIGURE 1

The important picture is that there are no unused bands of frequencies shown on Figure 1. Any new use of RF has to take spectrum away from someone else. The rest of this article will describe how cellular telephones and wireless personal devices have been taking RF spectrum away from traditional RF uses.

TELEVISION HISTORY

In the 1930s, television experiments were demonstrated and proponents were asking the FCC to allow them to begin transmitting pictures to the public. The Radio Manufacturers Association (RMA) proposed a television standard but not everyone accepted the standard. Finally, the FCC declared that until there is a nationwide standard, there would be no public television.

Very quickly, TV stations went on the air and the thirteen channels were filled in major cities. Around 1950, the military returned most of the UHF spectrum to civilian use and in 1952, UHF TV Channels 14 (470 MHz–476 MHz) through Channel 83 (884 MHz–890 MHz) were made available for television.

Note that UHF TV Channel 37 is reserved through international agreement for astronomical radio telescopes. No high-power transmitter is allowed on this channel to protect those observations.

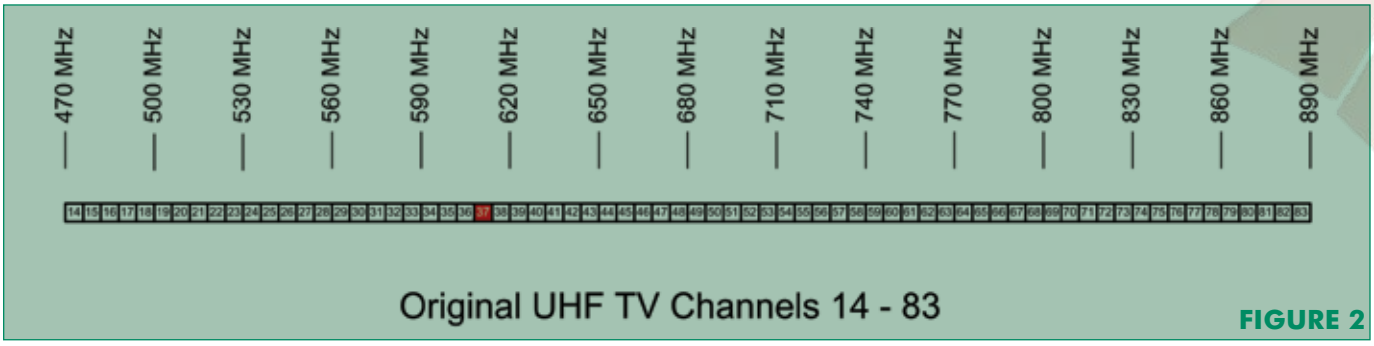


FIGURE 2

The National Television System Committee (NTSC) was formed in July 1940 to create such a standard. Meetings were held and every part of television broadcasting was reviewed. In March 1941, an FCC hearing was held and a consensus standard presented by the NTSC. The FCC adopted those standards and allowed television broadcasting to start with what is known today as NTSC 525-line television.

Different incompatible television channel plans had been proposed but in April 1941, eighteen television channels were assigned in low-band VHF (50 MHz–108 MHz) and high-band VHF (162 MHz–294 MHz).

World War II stopped all television progress as all of the VHF and UHF bands were assigned to the military for "the war effort" and consumer manufacturing was converted to military needs. After the war ended, the TV channel plan was changed again to make space for high-band VHF FM broadcast 88 MHz–108 MHz, leaving thirteen television channels in low-band and high-band VHF. The FCC was also pressured to make more frequencies available for land mobile communications so television Channel 1 (44 MHz–50 MHz) was taken away from broadcasting and assigned to land mobile communications. That's why with the exception of the very first-generation television sets, all US televisions start at Channel 2.

UHF TV stations had a problem because TV receivers only received VHF TV Channels 2–13. To receive any of the UHF channels, one needed to purchase a special "set top" converter. This required user-proficiency because the UHF tuner didn't have click stops and the user had to carefully tune in the UHF channel. Generally, TV antennas were VHF only and did not pick up UHF stations well. Another problem was that the UHF band had a lot more loss and first-generation UHF television transmitters had relatively low power.

Many new UHF stations went broke in a year or two and disappeared because viewers were unable to find the stations and without an audience, the station had no cash flow.

Finally, Congress passed the All-Channel Receiver Act of 1962. It required all television set manufacturers to include built-in UHF tuners in television receivers sold after 1964. Gradually, more television sets could receive UHF channels and with improvements in UHF transmitters for much higher power, UHF TV stations started to gain an audience and stay in business.

"T BAND"

By the mid-1960s, in many major metropolitan areas, land mobile communications, both public safety and industry and business, completely filled the available radio spectrum and started to pressure the FCC to make additional spectrum for their purposes. They proposed that several "unused" UHF TV channels be reassigned to land mobile communications. Finally, the FCC issued a Report and Order in May 1970 and in thirteen metropolitan areas, UHF TV channels were reassigned to land mobile communications. Since that time, there have been many rule makings fine-tuning the use of UHF TV frequencies in those areas.

"800 MHZ"

Two different forces converged to get the FCC to reassign UHF TV spectrum. The first was land mobile communications, which needed even more spectrum for their needs and the second was a new service called "Cellular Telephones." They proposed to the FCC that the upper UHF TV channels were lightly used and could be reassigned for their purposes. The FCC ultimately agreed and effective October 18, 1982, reassigned UHF TV Channels 70 (806 MHz–812 MHz) through Channel 83 (884 MHz–890 MHz) to these purposes. Because there were only a few UHF TV stations operating in these channels and there was plenty of otherwise unused UHF TV spectrum, this had little impact on television broadcasting.

Figure 3 shows the upper channels lost to UHF TV.

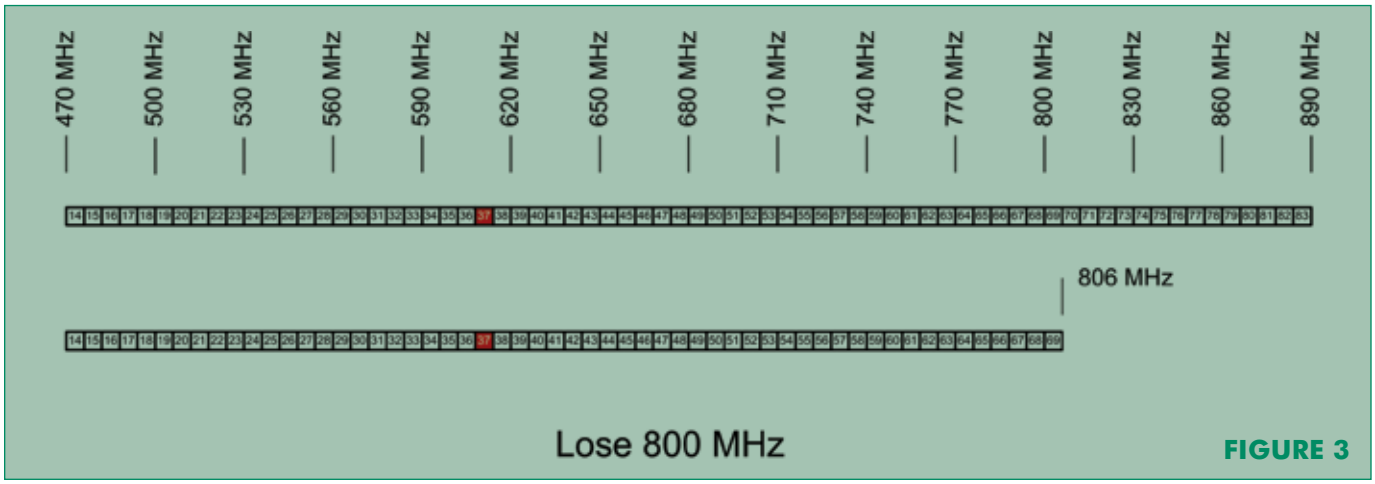


FIGURE 3

DIGITAL TELEVISION

In the 1980s, television set manufacturers started clamoring for "digital television." Their goal was to make all of the television receivers in the United States obsolete and sell new ones to consumers. Television broadcasters pushed back because (1) none of the proposed digital television systems actually worked; (2) it was going to cost stations lots of money to convert; (3) television stations realized that they could not charge more for a commercial delivered digitally; and (4) until the majority of viewers had new digital television sets, they would have no audience.

It became obvious that a nationwide standard needed to be adopted. The manufacturers remembered the Beta vs. VHS debate and did not want to go through incompatible systems again. So the Advanced Television Systems Committee (ATSC) was created in 1982 to take the competing digital systems and create a consensus standard. Ultimately, what is called the "Grand Alliance," developed a specification for what is known today as "ATSC 1.0." This standard included standard-definition format (NTSC) as well as high-definition (HDTV) standards. HDTV allowed a widescreen 16:9 image with about six times the resolution of NTSC.

The problem now was convincing the television broadcasters to convert to digital. In 1996, Congress authorized the distribution of an additional broadcast channel to every full-power TV station so that each station could launch a digital broadcast channel while simultaneously continuing analog broadcasting. Existing analog NTSC stations could have a second digital ATSC channel until enough digital receivers were in use in the United States. When this process was over, the television industry had to give up about 100 MHz of spectrum, the "700 MHz band" from Channel 52 to Channel 69. This process took a lot longer than expected partially because the new digital transmission and reception technology had to be developed, new transmission systems had to be purchased and installed (at a typical station cost in the range of $1 million), and viewers had to purchase new digital ATSC receivers. The viewers

had some help in that free converters were made available to the public funded by the sale of the "700 MHz band."

Originally, the transition date was February 2007 but it was clear at that time that not enough TV stations were ready to transmit digital and not enough viewers were ready to receive digital TV. The date was extended several times and finally on June 12, 2009, digital ATSC replaced analog NTSC throughout the United States. When this happened, the UHF television band was reduced to Channel 14 through Channel 51. But the carriers started to complain about interference from Channel 51 so TV stations on this channel had to move to another unused TV channel. Although Channel 51 still exists, in practice it is not used by TV stations.

Figure 4 shows the UHF TV spectrum as it exists today in 2016.

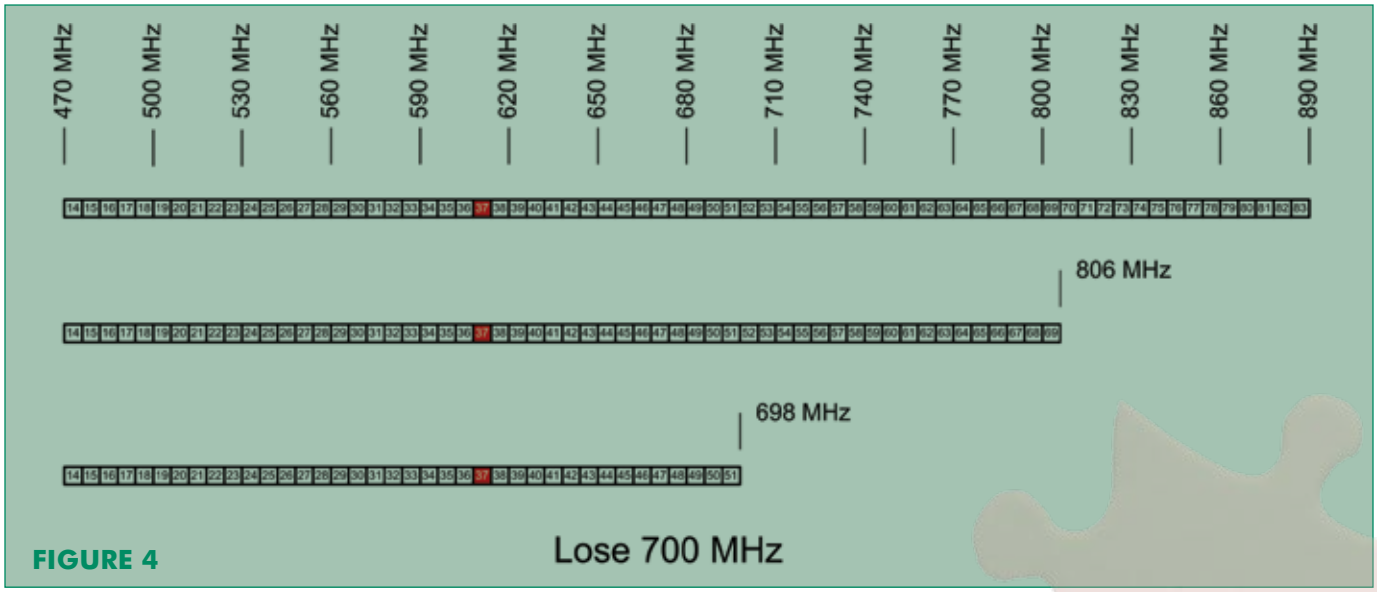


FIGURE 4

THE SPECTRUM ACT OF 2012

Buried in the Middle Class Tax Relief and Job Creation Act of 2012, Congress directed the FCC to sell about 100 MHz of the UHF TV band, now commonly referred to as "600 MHz." This legislation came as a complete surprise to the FCC, the broadcast industry and the mobile carriers.

Since that time, there has been considerable debate over exactly how this can be done and how this should be done. There are competing issues at stake. First, enough UHF TV channels must be cleared of existing television broadcasters nationwide to make a nationwide block of frequencies available to carriers. Second, new channels have to be found for these TV stations to move to. Third, the block of frequencies must be sold at a high-enough price to pay the TV station's cost to move and leave a profit to the United States.

Keep in mind that the Spectrum Act requires that the auction provide positive cash flow to the US Treasury. Not all FCC spectrum auctions have been successful. In this case, if the UHF TV stations demand premium dollars for their channels and the carriers hold back, the auction fails. Then the FCC has to revise its plan unless Congress changes the law. When this is over, a significant amount of UHF TV spectrum will be lost and it is likely that there will be no "unused" UHF TV channels.

WHITE SPACES

Several groups, including Microsoft, Google, Dell, HP, Intel, Philips, Earthlink and Samsung, proposed technology to use "unused" UHF TV channels for high-speed Internet access. These devices were termed "White Space Devices" (WSD).

After testing and lawsuits, the FCC approved the unlicensed use of white space on November 4, 2008. However, there were several limits imposed on the use of WSD that has limited their use. The major issue is that after the 700 MHz band was taken from broadcasting, there were few unused UHF TV channels or "White Spaces" left. Because these devices are unlicensed, FCC Rules require that they must operate without interference to licensed devices. The FCC mandated a system where licensed users and locations that use Broadcast Auxiliary Services like theaters or sports complexes can register that location and TV channel and all WSD in that area must shut down. While there have been a few demonstration systems installed, in general, WSD is a dead issue with no profitable business model.

ATSC 3.0

The digital television standard now in use is about twenty years old. Technology has greatly improved since that time and today there is an active research effort to define improved television quality with a new standard. Higher definition video, known as "4K," and an improved RF transmission system known as "COFDM," has been proposed. However, the proposed standard, termed "ATSC 3.0," is incompatible with the existing system and exactly how the US can transition to a completely new television transmission system has not been decided. The primary obstacle is that there are no "unused" UHF television channels today and after the 600 MHz band is taken away, it will be even more difficult to make the transition.

THE MOBILE TELEPHONE INDUSTRY

There have been mobile telephones since the 1950s. The first generation of mobile telephones used land mobile technology with high-level transmitters. This limited the number of mobile telephone users in any area. The hardware itself was large and required a lot of electrical power so the use was limited to automobiles.

In spite of the problems, there was considerable demand for mobile telephones by the 1960s. A user had to wait a considerable amount of time for a channel to become available to use their mobile telephone and because the number of users was limited, there was also a long waiting list of prospective users that wanted a mobile telephone number. Engineers at Bell Labs came up with a completely different type of mobile telephone system, which instead of high-level transmitters, used a network of low-level transmitters. The goal of this system was frequency reuse so that more active mobile telephone users could be accommodated in limited spectrum. A lot of intelligence was necessary to make this work, both at the network level and at the subscriber level because as one moved around, the call would be "handed off" to a different transmitter and frequency. Because diagrams of this system showed a neat arrangement of octagons, it became known as "cellular" telephones.

First-generation cellular telephones were analog and took advantage of 800 MHz spectrum taken away from UHF TV channels. Although the first-generation electronics were large enough to require trunk mounting in automobiles, the demand for these telephones was huge. The cellular providers quickly were behind in installing more and more network equipment to handle the demand.

Eventually, the network caught up with the demand and the service became highly profitable. Technology improved to the point where one could have a handheld cellular telephone. First-generation handheld cellular telephones were big and heavy and were known as a "brick" because they resembled a brick in size and weight.

The industry also recognized that they needed more spectrum to carry the demand so they petitioned the FCC to find more. The next generation of cellular systems was at a much higher frequency, around 1.8 GHz–2 GHz. Both US government stations and private microwave stations were relocated to other spectrum with the costs being paid by the carriers. These new cellular systems were digital and much more spectrum-efficient than the first-generation analog telephones.

The industry learned that the key to keeping up with the demand for capacity was to keep reducing the size of the cells. Today, one sees references to "micro-cells" and even smaller "pico-cells." To make this happen, antennas must be designed to minimize coverage and the higher 1.8 GHz–2 GHz frequencies are preferred.

Also, the industry having completely converted to digital found itself providing data services as well as voice services. At first, short text messages were supported but as technology improved, full Internet access and email became available. Combined with much improved handsets, known as "smartphones," a user today has much more communications ability than just making voice calls.

This also dramatically increased the need for capacity. The cellular industry simply cannot install new equipment fast enough to keep up with the demand. The industry continues to ask for more spectrum for additional capacity. They have learned that the higher frequencies work much better for small cells and are looking at frequencies up to 5 GHz.

But Congress, with the Spectrum Act of 2012, proposed to make 600 MHz available for this purpose. The lower frequency is not as attractive to the cellular industry for several reasons. The first reason is that the handheld antenna becomes too long to fit into today's small handsets. The second reason is that the coverage is too good for efficient spectrum reuse. The third reason is that transmit antennas become much larger for equivalent performance than the higher preferred frequencies.

Exactly how the cellular industry will respond to the 600 MHz auction is not known. Already, one carrier, Sprint, declared that they would not participate in the auction.

The FCC has spent a lot of effort working on the auction

and at the present time, no final road map for the auction has been proposed. They did publish a chart of potential frequency use, which has a range of potential scenarios from only two broadband blocks to twelve broadband blocks. The scenarios are messy because the broadband blocks are 5 MHz wide while TV channels are 6 MHz wide; TV Channel 37 must be protected; and the broadband blocks must have an 11 MHz guard band between the uplink and downlink blocks. Depending on the scenario, there is a minimum of 3 MHz of unused spectrum to a maximum of 11 MHz of spectrum that might be available for wireless microphones.

Figure 5 illustrates the complexity of the Spectrum Act's requirements. The very top line shows the UHF TV spectrum as it exists today. But then the figure shows eleven different scenarios with two to twelve blocks becoming available for auction. What nobody knows today is how many UHF television stations will desire to sell their channel; how many carriers will bid on potential blocks; and what may be left for low-power auxiliary devices like wireless microphones. Since the downlink and uplink block pairs will be sold on a country-wide basis, the market with the fewest UHF TV stations that decide to sell out will define the scenario throughout the United States.

There is an active debate on whether the 11 MHz guard band will allow one UHF TV station to operate in the guard band. The carriers do not want a high-power UHF TV transmitter to interfere with their customers. There is also another guard band between downlink blocks and UHF TV channels. This is an attempt to reduce potential interference from nearby carriers' transmitters and UHF TV reception. The guard bands have the potential for wireless microphones but one must consider that a nearby cell tower could make use of these guard bands for production very challenging.

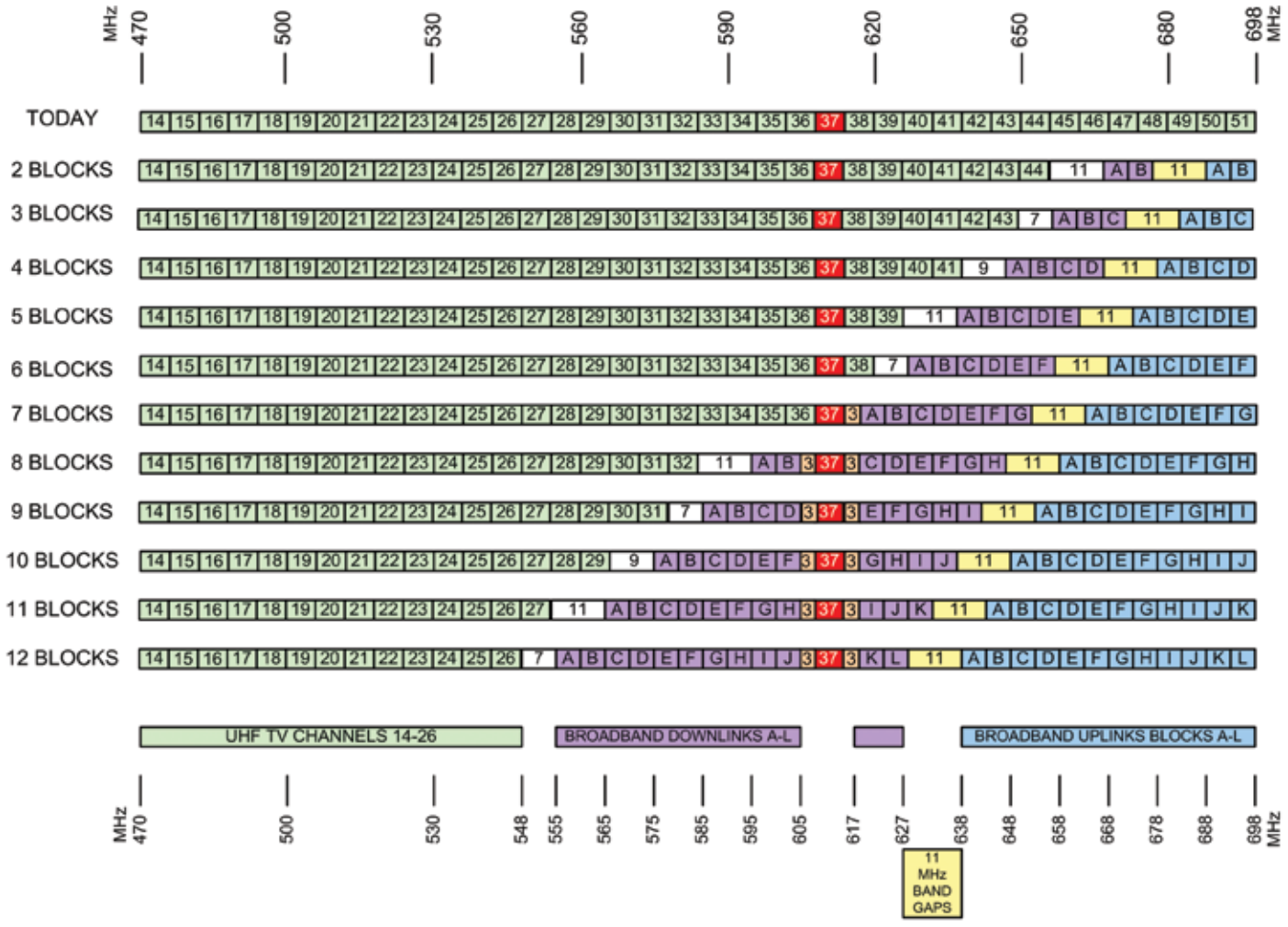


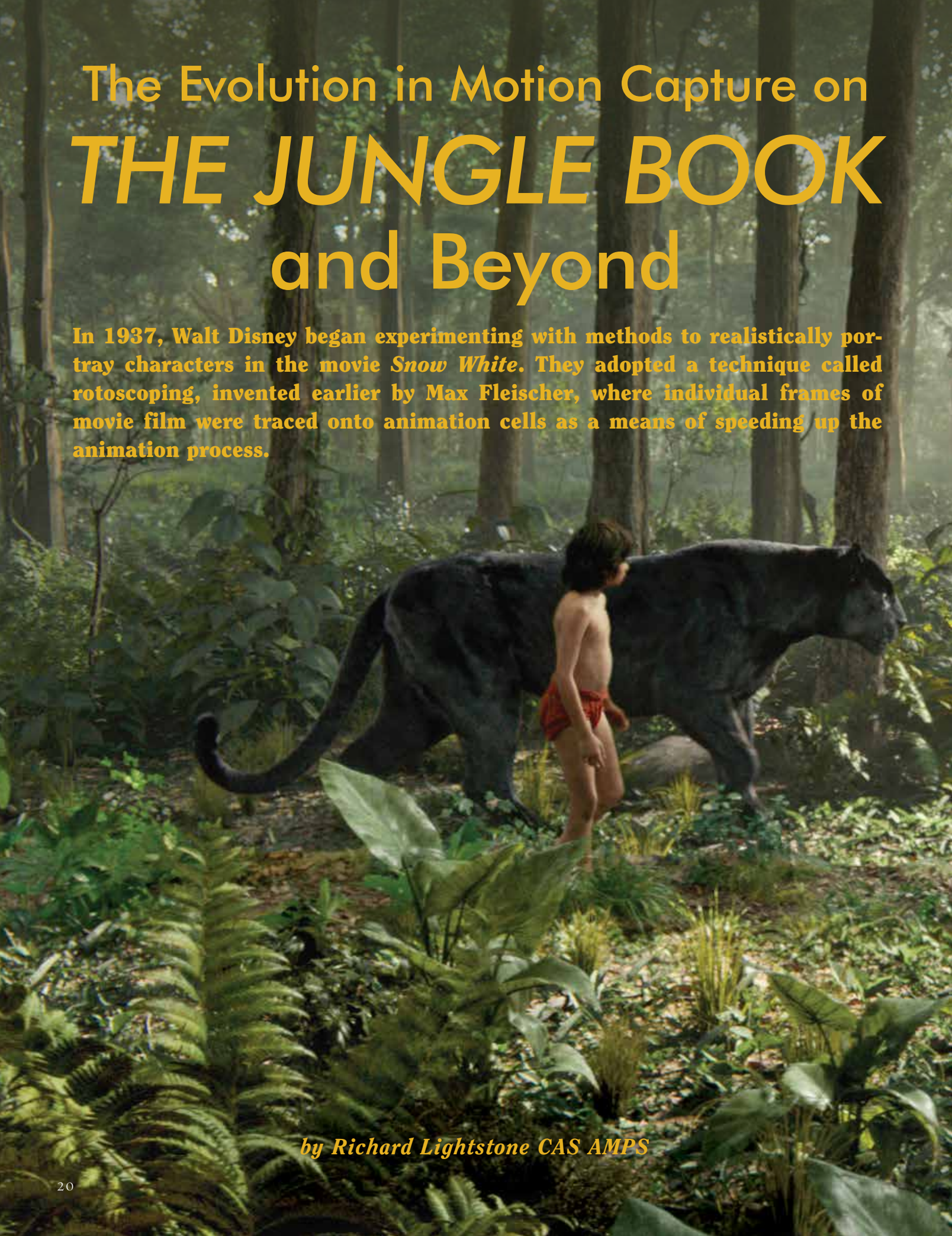
FIGURE 5

POTENTIAL 600 MHz SCENARIOS
BASED ON FCC 14-50 FIGURE 23

Part 2 of "The Radio Frequency Spectrum Puzzle" will continue in the summer edition.

The Evolution in Motion Capture on *THE JUNGLE BOOK* and Beyond

In 1937, Walt Disney began experimenting with methods to realistically portray characters in the movie *Snow White*. They adopted a technique called rotoscoping, invented earlier by Max Fleischer, where individual frames of movie film were traced onto animation cells as a means of speeding up the animation process.



by Richard Lightstone CAS AMPS

Leaping forward four decades with the advance of computer processing, 3D animation was used in the motion picture *Futureworld* (1976). As technology and computer speeds improved, new techniques were sought to capture human motion. A more sophisticated, computer-based motion tracking technology was needed, and a number of technologies were developed to address these developing human images.

What Is Motion Capture, written by Scott Dyer, Jeff Martin and John Zulauf in 1995, defines the process as "measuring an object's position and orientation in physical space, then recording that information in a computer-usable form. Objects of interest include human and nonhuman bodies, facial expressions, camera or light positions, and other elements in a scene."

The majority of motion capture is done by our Video Engineers of Local 695 and requires high technical skills at problem solving often in the form of writing new software.

Glenn Derry and Dan Moore are perhaps the busiest and most experienced in the field of motion capture with credits such as *Avatar, Tin-Tin* and *The Aviator*. I spoke with Dan at their new seven-thousand-square-foot facility in Van Nuys and Glenn and Dan a week later via a phone conference in Vancouver and Atlanta respectively. Their most recent screen credits include the sophisticated and elegant imagery seen in Disney's *The Jungle Book*.

Glenn Derry describes the unique challenges of their work on *The Jungle Book*. "We've got the character Mowgli, played by Neel Sethi, and he's the only live-action element in the entire picture. All of the work in terms of shot design has happened months before in a completely virtualized environment with the Director of Photography, Bill Pope, holding the camera and creating the shots, and working with the CD (Computer Design) team to come up with the look. We were lighting our physical elements to match the CD in contrast to the traditional shooting of live action driving the computer graphics." Dan continues, "We designed a way to track the camera in real time so that we could overlay their hyper photo realistic virtual scenes, shot months before and mix it with the live action as we were shooting in real time."

They shot on multiple stages requiring video feeds in every location, interfacing all the tracking cameras, deliverables and dailies for editorial. Dan and Gary Martinez managed a large server with the master footage while designing solutions for Director Jon Favreau. Derry, Moore and Martinez came up with an elegant solution to project shadows in real time on Neel, who was walking on a forty-foot turntable.

"We were always developing software," Derry continues. "On *The Jungle Book* in particular, we wrote a few different applications including a delivery tool that enabled them to view all of the material. One piece of software that we at Technoprops wrote for the show dealt with color reconstruction of the camera raw images." 'Debayering,' a common term used for this process, was named after Dr. Bryce Bayer at Eastman Kodak. "Once the software was written, we titled our process the 'De Bear Necessities,' and delivered this to editorial and production. Normally

Opposite page: Mowgli and Bagheera walking through the jungle. Top: *Snow White* 1936 rotoscope work; 3D CAD model of a head rig.

a convoluted, complicated and expensive process now was estimated to save production between one and two hundred thousand dollars."

Previously, the director and producers would need dailies starting from a specific beginning and going to an end point, which was complicated, time-consuming, and expensive to load and combine with essential data. Because of the need to generate the visual effects in the deliverables, they wrote new code that any editor could use to drag an EDL (edit decision list) into a folder and automatically generate exactly what visual effects were needed in their deliverables.

Using a system from the company Natural Point, and their OptiTrack cameras, they built a half-dozen moveable twenty-five-foot towers containing six motion capture cameras each. Glenn explains, "The system that we built integrated the OptiTrack motion capture system with our own camera hardware and software, this was high-end inertial measurement unit data that was on the cameras. We created a hybridized optical inertial tracking system allowing them to choose how much of this was coming from the inertial center versus the optical motion capture system.

"Further, in-house, we developed infrared active markers that allowed production to work in an environment where you could do real set lighting and still be captured by the motion capture (Mo-cap) cameras; a big breakthrough in our industry. If we could register the live-action camera from at least three of the six movable towers, then the live movable object (prop and or actor) within the volume and the virtual *Jungle Book* world would be aligned or calibrated."

"On the performance side," adds Derry, "what we're really doing is capturing the actors and trying to record the essence of what they do and combine that with the 'jungle' world as quickly and efficiently as possible. We need to visualize the image for the director and the DP."

Moore adds, "How do we figure out how to have a virtual bear (Baloo) walking next to the actor within the confines of a stage, so it looks like they're walking through the woods? These were one of many challenges that would come up frequently during the course of production. We also needed to have the virtual and live-action elements combined and represented on the monitors, which were placed around the set. Glenn Derry came up with the solution for the 'Baloo and Mowgli' challenge and decided on a turntable, with the ability to articulate the movement along with his motion control base to make it all come together."

"We worked with Legacy Effects, who make really well articulated animatronics," explains Robbie Derry. "Their job was to make Baloo, a bear, so they manufactured a shell that rides on a motion control base. Neel would sit on it as if he was riding Baloo. The motion base has a 360-degree rotational top as well as a 30-degree tilt, pan and roll."

They could import the final animation data into the onset computers and drive the camera and the motion base simultaneously to get the true movement of what Neel should be doing in the scene.

Robbie Derry continues, "When we played back the animation on top of the real-world scenario, through camera, you could see Neel riding on it, with the full background, the bear was moving, the bear was turning, and we were capturing all this in real time, which was a really cool thing to be able to do. It allowed the director to be able to line up shots correctly; and move the camera on the fly. We could track where that camera was in 3D space, on the stage, at any time, and then back feed the animation cycles through the lens. So, when you're looking through the camera, you could see the bear. I could walk around with the camera and see the bear from all sides. This is something you couldn't do prior to being able to track camera data like this."

The heart of Technoprops and Video Hawks opera-

Top row: Dan Moore; Dan Moore and the machine shop; Moore working the set; the OptiTrack cameras; the Baloo turntable rig. Second row: Moveable tower with OptiTrack cameras; there were six moveable Mo-cap towers; Robbie Derry operating the turntable. Third row: (from left) Glenn Derry, Dan Moore and Gary Martinez; live action and a final rendering of Mowgli and Baloo

tion is at a facility in Van Nuys. Its two floors are crowded with equipment. Dan is very proud of the machine shop managed by Kim Derry, his son, Robbie. Angelica Luna, Gary Martinez, Mike Davis and others are also an integral part of their companies. The shop contains three Computer Numerical Control (CNC) machines where they can fabricate whatever they might need for a project, from custom head rigs to the carts and the frames that hold components. Dan explained, "Having the metal shop here, and the talent just allows you to respond very quickly to what's needed, rather than having to sub all this work out."

One of the many creative technologies available in their facility is a Vacuform machine that makes precision molds of actors' faces, enabling the green registration marks to be placed in exactly the same place day after day. The green tracking markers are used by the Computer Graphics house to track the movement of the facial muscles.

They also manufacture the active markers with surface mount LEDs that can glow green or emit an infrared signal that can be used in exterior light. Computer gaming and motion capture films often use actors in black suits who wear reflective markers over their body. This allows a computer to see the movement of the actors and later reconstruct the movement with the character from the story (i.e., Neytiri from *Avatar*). This often would take place in an indoor environment with even overall lighting. With Active Markers, virtual actors can interact with live actors, in an outdoor or indoor environment, and use traditional set lighting.

Robbie Derry does the 3D CAD design and the 3D printing of the custom-fitted head rigs with a single arm holding the 2K high-resolution cameras that are capable of shooting at 120FPS for facial capture. Each actor wears a small custom-made computer serving as a video capture recorder. They can tap into these recorders wirelessly, on their own Wi-Fi network using Ubiquity routers built into Pelican cases. With their Web application, they can use a cellphone, iPad, or any device to watch the video back and also function as a confidence monitor.

Before the technological advances developed by the motion capture industry, the old paradigm of Mo-cap involved an animator sitting at a computer with the director, or the DP, having to decide what live-camera shots were needed, and what set construction was required. Now we are capable of putting new tools in the hands of directors and directors of photography, enabling them to create scenes from their imaginations in real time instead of waiting for the animators and the computer modelers to generate their environments.

Glenn Derry sums it up, "The end result is the creation of a virtual reality, where the director can interact with all the actors and elements in real time. Teamwork is key because there's so much integration between pre-visualization, live action and post production. Ninety percent of our entertainment will be generated in virtual reality in the near future. We are doing the groundwork for what will be the norm in ten years."

"Walt Disney would be impressed with today's technology," says Moore. "On *Jungle Book*, Technoprops and Video Hawks served a creative team of filmmakers and a director's imagination. Virtual reality technology will have an impact on our entire industry and the members at Local 695."

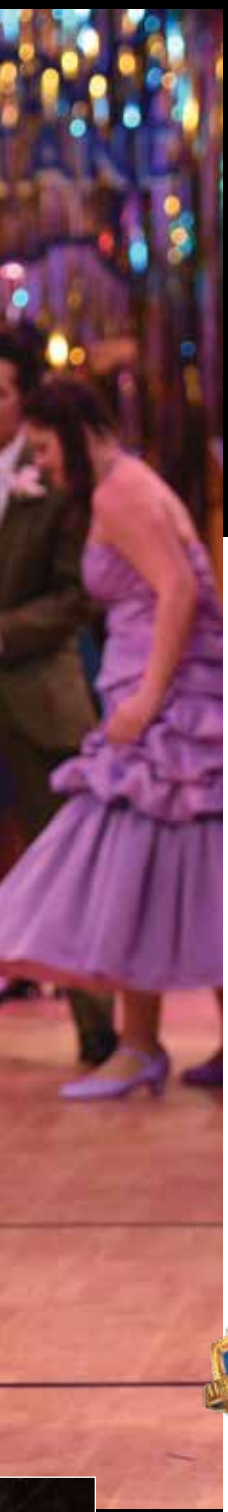
Balance Is the Word

The Wireless Microphone and IEM Systems for *Grease Live!*

by Dave Bellamy

The Prom: Danny Zuko, played by Aaron Tveit, and Sandy, played by Julianne Hough, dance it up.
(Photo: Kevin Estrada 2015)

Right: The cast celebrating the finale of the Carnival set for *Grease Live!*
(Photo: Kevin Estrada 2015)

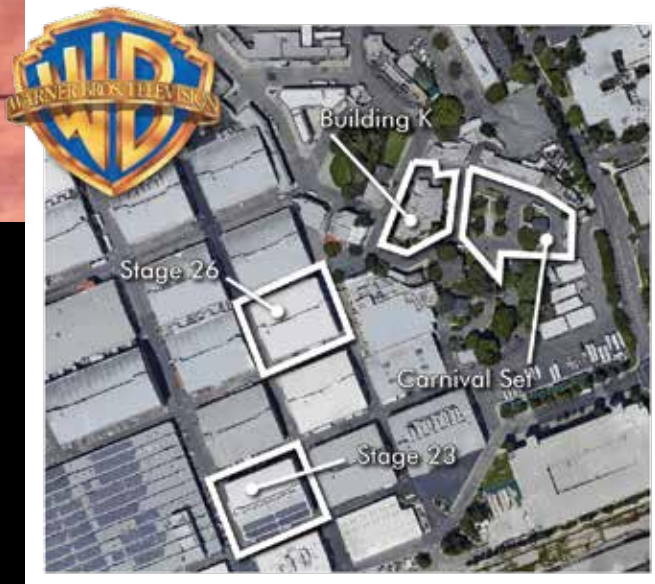


It started as it usually does with a simple phone call. The call was from longtime friend Bruce Arledge. He said that there would be a production of *Grease* and that he was the Sound Designer. The show would be produced at Warner Bros. Studios Burbank and it would air live January 31, 2016.

He went on to say that there would be fifty-three wireless microphones required and as yet undetermined quantity of IEMs. The show would take place on multiple stages and that the microphones have to be supported by one antenna system regardless of where they were being used during the show. He also noted that Jessie J would open the show with a walk, singing live, with ear monitors and that she would begin on Stage 26 and end in front of the set of Rydell High School traversing a distance of more than six hundred feet. He knew that we had an antenna system (the Phoenix system) that was capable of successfully doing this type of project. He also said that he and Mark King, the Production Audio Mixer, had conferred and agreed that Soundtronics was probably best suited to do the show. Would we be interested? Jason Bellamy, the Managing Partner of Soundtronics, took the call, thanked him for the opportunity and said we were.

At the first production meeting, with stage plots and a map of the Warner Bros. lot in front of me, I began to become aware of the overall scope of this project. The show would encompass fourteen sets over twenty acres of real estate. I remembered having a conversation with Mr. Arledge and hearing him say that most of the scenes take place on Stages 23, 26 and the Rydell High School set, which on the Warner Bros. map was known as the K building located on the backlot. Another look at the map showed that Stage 26 was almost equidistant between Stage 23 and the K building. The next step was to schedule a site survey where detailed measurements could be taken.

The findings of the survey were far from being favorable, at least from an RF spectrum perspective. The RF environments in Stages 23 and 26 were relatively friendly. Both stages fairly well shielded with wire mesh on the walls and ceiling, Stage 23, being the better of the two. In the K building/Rydell High School, we were not as fortunate. There was next to no RF shielding in this building. The structure offered protection from the sun and very little more. The RF environment in the open areas outside of the structures can only be described as hostile. LA is a huge market with wall-to-wall DTV channels in the 500 MHz to 700 MHz frequency ranges. Channel 19, 500 MHz–506 MHz was the only exception. Every other channel had DTV in it at some level. Additionally, Channel 19 is no bargain. At that frequency, there is usually enough local interference caused by other electronics on stage to raise the noise floor 6 dB to 8 dB or more. In some cases, Channel 19 can be more difficult to work in than a low-power DTV channel.



The Warner Bros. Studio lot and the fourteen sets over twenty acres for *Grease Live!*

Luckily, more than seven of the DTV channels that registered on my spectrum analyzer were from out of the area and were legal to use at the Warner Bros. location. I selected the best three of those and that is what we went with. That netted us 24 MHz of dirty spectrum in which we need to get twenty-four microphones to work seamlessly. I remember feeling confident at the time that we could do that, but we needed fifty-three, leaving us twenty-nine microphones short. To make up for this shortfall, we had to find more usable spectrum. The first thing we did was apply to the FCC for special licensing so we could gain access to the spectrum between 944 MHz and 960 MHz. This would buy us 16 MHz of bandwidth that would yield eighteen usable frequencies. The second thing we needed to do was gain at least partial use of the ISM band. This is the band between 902 MHz and 928 MHz. To be able to successfully operate in these frequency ranges, we would need to have the full cooperation of the Warner Bros. frequency coordinator, Ara Mkhitaryan, and that is exactly what we got. He could not have been more helpful. Thanks to him, we were able gain access to 11.5 MHz in the ISM band that would yield fifteen usable frequencies. Let's see now, 24 + 18 + 15 = 57 and we needed 53.

Jessie J rehearsing her opening walk. (Photo: Daniel Weddick)

Master RF rack on Stage 26

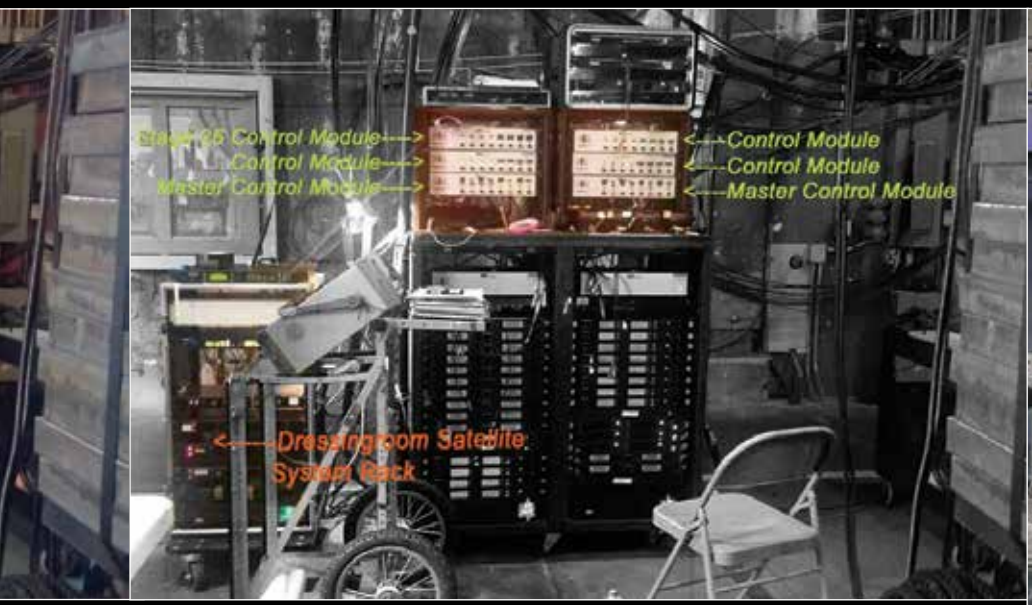
About two weeks after the RF survey, we conducted another survey purely for the purpose of measuring the property. Every stage; the distance between stages, every performance area and the distance between performance areas and every potential cable run. After reviewing my measurements, I decided that along the north wall of Stage 26 would be the best place for the master RF rack. The satellite rack on Stage 23 would also be placed along the north wall near the cable access ports for that stage. The satellite rack for the K building would be located in the tech center behind the Rydell High School hallway set.

There would be four intermediate cable runs that would link the satellite antenna rack on Stage 23 to the master rack on Stage 26. These cable runs were six hundred feet in length each. There also would be five intermediate cable runs that would link Stage 26 to the K building; four for the satellite system and one of them for the Jessie J in-ear monitor system. These runs would be seven hundred and fifty feet in length each.

The design of the system would be straightforward. We would break the project into four zones: Stage 26, the Dressing Rooms, the K building and Stage 23. Each zone would have a discreet Phoenix satellite antenna system that would operate independently of the other three satellite systems. All four systems would be combined at a master system rack location on Stage 26. Each system would be assigned an RF technician with a spectrum analyzer. I would be responsible for the systems on Stage 26 which would include the Stage 26 satellite system, the Dressing Rooms satellite system and the master antenna system rack which would also be the home of all of wireless microphone receivers. Corey Dodd would be responsible for the K building system and Grant Greene would be responsible for Stage 23 system. All four systems could be monitored from the master rack location on Stage 26. The K building and Stage 23 systems could be monitored locally.

Before we go any further, I think it would be appropriate to provide a brief description of the Phoenix system and some of the advantages of using it, especially in view of the fact that we will be using four of them on this show. We will begin at the antenna. The antenna is connected with a short piece of coax to a four-channel gain adjustable filter set, capable of providing 15 dB of gain. The gain is used to compensate for cable loss and nothing more. The filter set is connected to a much longer piece of coax that runs back to the RF rack where it is connected to a control module. The control module can power the filter set via the coax or power it down if necessary. The control module then feeds a band past antenna distribution amplifier (DA) which can feed up to thirty-two receivers. Since the filter is capable of supplying gain, the length of the coax is all but irrelevant. Two hundred and fifty feet is not considered to be a long cable run. The antenna can now be optimally placed virtually without cable length restrictions. A Phoenix VIII control module is capable of supporting eight filter set/antenna locations. If two Phoenix VIII control modules are used, one feeding the “A” side of the antenna distribution amplifier and the other feeding the “B” side of the antenna distribution amplifier, the system is capable of supporting sixteen filter set/antenna locations. Because each antenna can be optimally placed, the Phoenix system can be tailored to the show and the antennas focused on where the transmitters are actually working during the show. When balancing a Phoenix system, the frequencies in the 500 MHz to 700 MHz range are set at 8 dB below reference gain, the frequencies in the 902 MHz to 928 MHz range are set at 4 dB below reference gain and the frequencies in the 944 MHz to 960 MHz range are set at 2 dB below reference gain. The gain can be further reduced if necessary, either globally at the antenna DA or at individual antenna locations.

Our first official installation day was December 16, 2015. The schedule called for ESU of the entire property by the end of the day on December 17. There would be two dark days, then on-camera rehearsals would begin on Stage 23 on December



Above: Master RF rack explained. Right: The auto shop on Stage 23 (Photo: Kevin Estrada 2015)

20 and continue through the 21st. Two days wasn't nearly enough time for all that needed to be accomplished. But beginning rehearsals on the 20th was doable.

Luckily, the antennas on Stage 23 had already been flown and the intermediate cables had been run. All that remained was to move the satellite rack into place on 23, move the master rack into place on 26 and balance the system through to that point.

Stage 23 would require two Phoenix XIII systems. The high-range system would manage the bandwidth between 902 MHz and 960 MHz and the low-range system would manage the 500 MHz to 700 MHz bandwidth. At each antenna would be a dual-range filter set with two discrete antenna inputs. The high side would be fed by a Sidewinder antenna tuned to the 870 MHz to 900 MHz bandwidth. The low side would be fed by a Widowmaker antenna tuned to the 500 MHz to 700 MHz bandwidth. (Both of these antennas are proprietary Phoenix system designs.) This would be a twelve-antenna array system employing twenty-four antennas in all. The satellite rack itself would contain two control modules that fed two 30 dB line amplifiers for the high-range system and two control modules that fed two 20 dB line amplifiers for the low-range system. The outputs of each of the four line amplifiers would feed the corresponding inputs at the master control modules in the main rack on Stage 26.

To balance the system would require the implementation of two devices, a Reference Transmitter Kit (RTK) and a Live Motion Simulator (LMS). The RTK is an assortment of transmitters tuned to the center frequency of the passbands being used. The transmitters are built into a small road case within two outputs; a high range and a low range. The RTK is then patched directly into a spectrum analyzer and the amplitude of each transmitter is noted on a system test form. The RTK is then unpatched and an output of the antenna system is patched in its place. The RTK then moves to one of the filter

Thunder Road rehearsal on Stage 23
(Photo: Kevin Estrada/FOX)

“In the end, our balancing acts payed off. During the dress rehearsal and show, the receive antenna system worked beautifully, all four satellite systems performing in unison.”

set locations. The antennas are unpatched at that location and the RTK is patched in. The gains are then adjusted until they meet the afore mentioned specifications, 8 dB below reference in the 500 MHz to 700 MHz range, 4 dB below reference in the 902 MHz to 928 MHz range and 2 dB below reference at the 944 MHz to 960 MHz range. The RTK is then unpatched and the antennas reconnected. This is repeated at all antenna locations. The same RTK is used throughout all of the antenna locations on the show. The RTK is also used to balance the intermediate cables between Stage 23 and 26. The specifications for these runs were reference plus 0 dB or minus 1 dB.

Now we know that all of our lines are balanced but we still do not know how well the antennas are working. To qualify the performance of each antenna, we implement the LMS. This device is placed on the set well within the beam width of each antenna to be tested. Reference transmitters are mounted on the LMS where they are rotated continuously 360 degrees in a circle four inches in diameter. Utilizing the peak hold setting on my analyzer, I can determine if I am receiving the amplitude that I expect to see and if there is parity among all of the antennas in the system.

Looking from more of a theatrical perspective, Stage 23 would be the location of the Frenchy’s House, USO, Auto Shop, Lovers Lane, Drive In and Thunder Road sets. Rehearsals would begin on time and go well. Now it became a matter of installing the rest of the systems while staying ahead of the rehearsal schedule at the same time. Rehearsals would begin on Stage 26, the hub of the design wheel, on the 22nd. That gave two days to complete our work there.

The installation of the satellite systems for the stage and the dressing rooms was fairly routine. Both systems were tuned and balanced to the exact same specifications as the system on Stage 23 had been. There were more antennas involved, thirty-one in all. But that was because both systems shared responsibility for the streets on the east and south sides of the building. The main system on Stage 26 was twelve arrays and twenty-four antennas, just like the on Stage 23. Our primary concern and top priority was the performance of Jessie J’s ear monitors during her opening walk from Stage 26 to Rydell High. The walk wouldn’t be rehearsed until the afternoon of the 27th, but the 25th and 26th were dark days. This meant that the system had to be performing to the satisfaction of the monitor audio boys by the end of the day of the 23rd. This way, if there were issues, we had the day of the 24th to fix them. There were no issues. The system worked seamlessly the time it was first tried and every time thereafter. We could now move onto the K building.

The K building satellite system was the largest of the four systems. It covered the second half of the Jessie J walk (the first half was covered by the Stage 26 and Dressing Rooms systems), the Boys to Men vocals at the halfway point of the walk, the front of Rydell High, the interior hallway of Rydell High, the principal’s office, the carnival set located beyond Rydell High on Midwest Street and Sandy’s house where Sandy would perform “Hopelessly Devoted to You.” The system and the seven hundred and fifty foot intermediate cable runs were balanced to the same specification as the system on Stage 23.

On January 29, we learned that the plans for the finale of the show had been realized. The cast would exit the Carnival set on Stage 26 through the west elephant door singing live. They then would board three awaiting trams that would turn left and drive along the east side of the building, then turn right and drive along the same route as the Jessie J walk was taken, drive past the Rydell High set to the Carnival set on Midwest Street. There they would then step off the trams and dance their way to the center of the Carnival set. They would be singing live the entire way traveling a distance of more than one thousand feet. There were sound systems on each of the trams that were fed track by ear monitor receivers located on each tram. These receivers were set to the same frequency as the transmitter that was used for the Jessie J walk. The antenna system coverage for both the wireless microphones would have to be expanded but not very much. We knew that something would be happening on the east side of the building and we were already covered for that. This meant that only two receive antenna locations would need to be added on the south side of the building to cover the wireless microphones. There was already an ear monitor antenna in place at the southeast corner of the building which covered the south side of the building nicely, which meant that the ear monitor coverage would not need to be expanded.

In the end, our balancing acts payed off. During the dress rehearsal and show, the receive antenna system worked beautifully, all four satellite systems performing in unison. In all, forty-eight filter sets, ten line amps, eighty-two antennas and twenty-two thousand feet of antenna cable were in use by the time the system was completed. It gets better. There were no complaints about the ear monitors, not one. Not bad when you consider that it took only six antennas and seventeen hundred and fifty feet of antenna needed to round out the system.

In closing, I would like to say that *Grease Live!* was a very worthwhile project and all of us at Soundtronics Wireless would gladly do it again.