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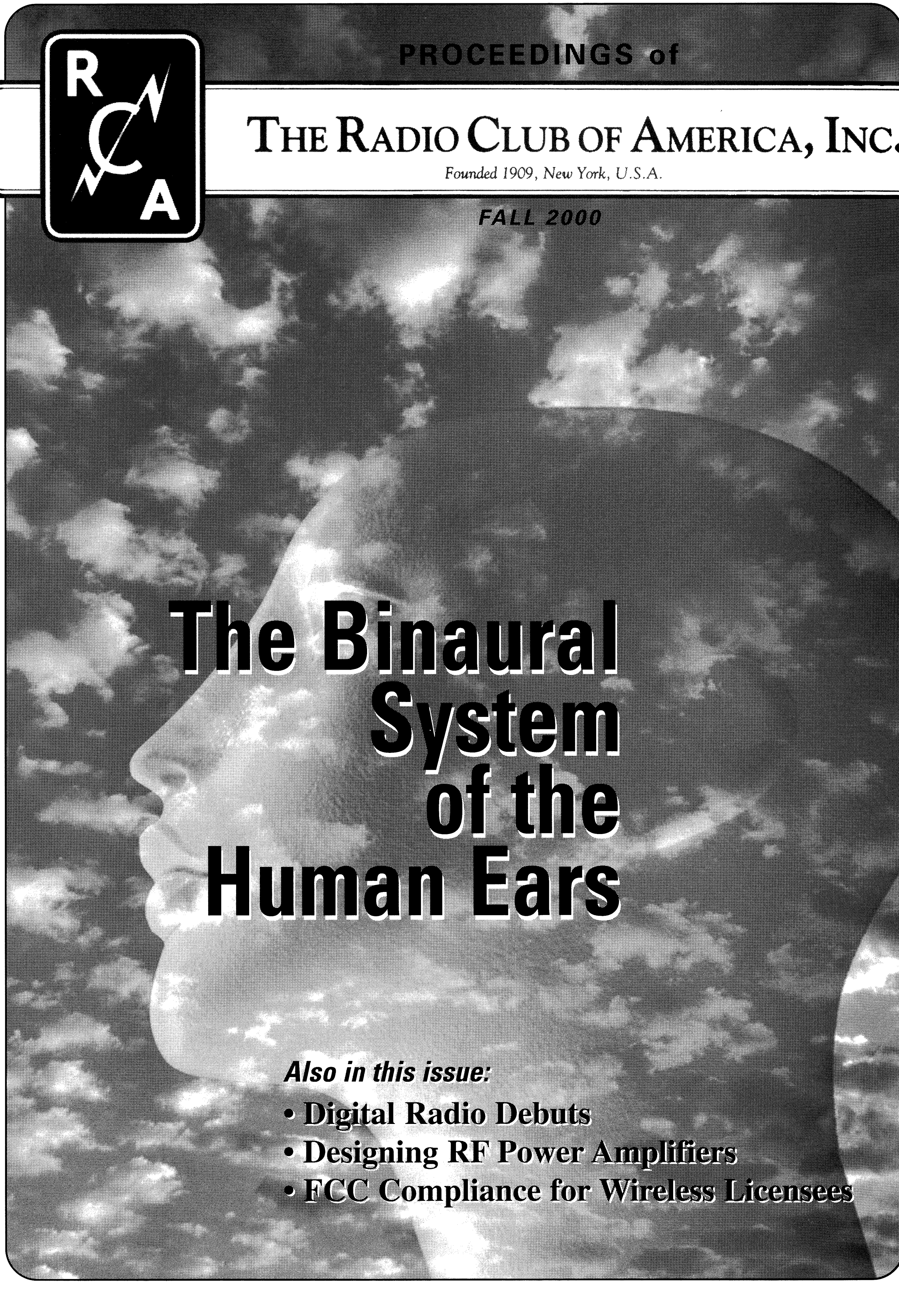
FALL 2000



# The Binaural System of the Human Ears

*Also in this issue:*

- Digital Radio Debuts
- Designing RF Power Amplifiers
- FCC Compliance for Wireless Licensees

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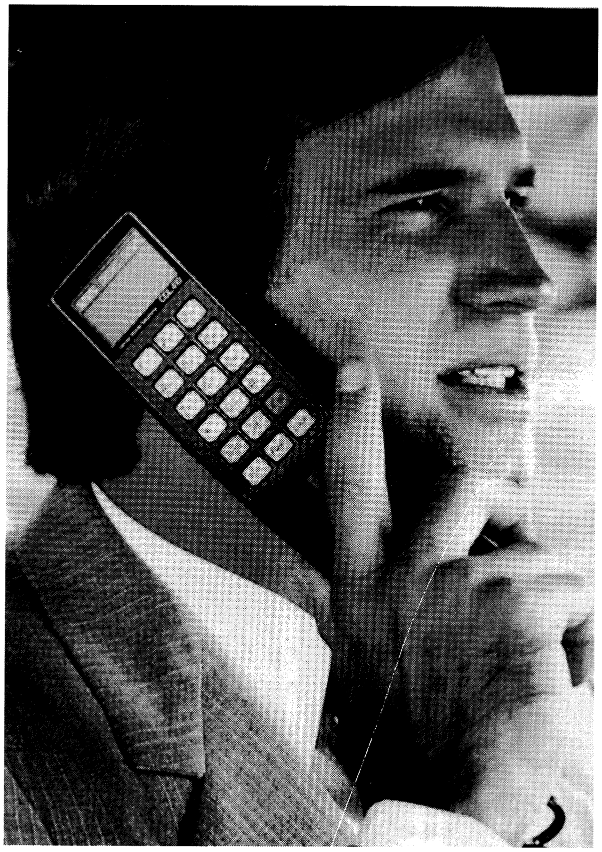

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By Jerry B. Minter

# The Binaural System of the Human Ears

The dictionary defines "binaural" as pertaining to the use of two ears instead of one. For perception of direction and acoustic perspective the use of two ears is essential, the facilities being lost in a monaural or single-channel system. The human sight nerve processes not only acoustic data from the ears but also optical data from the eyes and ultra sound from a little understood sensing system.

## Building Custom Aids

I constructed a binaural hearing aid in 1937 for Horace Scanlon, a famous photographer of the twenties. He was then able to function as master of ceremonies at our local photography club in Boonton, N.J. I located the microphones at each ear next to the audio earpiece. Fortunately the earpiece was magnetic and the microphone was piezo-electric, so there was no trouble with electrical feedback. However, there had to be some physical isolation to prevent mechanical feedback. The two amplifiers were in a small metal box usually carried on his belt. The small hearing aid tubes available from Raytheon and the miniature battery required little space.

Some years later I made up a binaural head set for our Radio Club secretary, Fred Shunaman, whose impaired hearing made it difficult for him to understand and copy comments from the assembled board of directors. I modified a small two channel Radio Shack cassette tape recorder so that Fred could play back the *Proceedings* and prepare the minutes of our meetings.

JVC actually built a model HM-200E binaural hearing headset, which was fed into a model KD-2 portable cassette tape recorder. I used this combination to record several of our Radio Club meetings. At the meeting I would naturally turn my head toward the speaker, thus focussing my recording and allowing the system in the eighth nerve to screen out stray room noise.

## The Binaural System

In addition to the bundle of nerves from the cochlea, there is an additional channel known as the "the microphone channel." In the past most doctors to whom I talked did not understand the function of this microphone channel. The cochlea is basically a spectrum analyzer and if two short audio pulses are fed into a mono loudspeaker and the spacing between the two pulses is reduced to less than fifty milliseconds the result sounds like one pulse to the person listening.

Now the distance between the two ears in about five or six inches or a time delay of about five or six milliseconds, so how can the cochlea determine any differential this short?

Furthermore, in my effort to locate a small two-channel audiocassette recorder I bought a Sony model TCS-430. To my surprise, the two small microphones were only 3/4-inch apart!

However, this small spacing is adequate to provide a binaural response on playback. The time differential is only 60 microseconds. So the data processor in the eighth nerve is able to compare the times of arrival as short as 60 microseconds. This has to be through the microphone channel rather than the cochlea.

### Direction Finders in Animals

Did you ever observe a small bird cock its head? It is likely locating the precise location of a sound - his acoustic direction finder. A small bird has ears only a fraction of an inch apart too. I have personally observed the microphone channel output from a small bat in the lab with a 50,000 cycle ultra sound source. Electrodes in contact with the top of the bat's head picked up the audio signal.

The household cat also has the microphone channel available on the top of its head but the eighth nerve in the human brain is buried and not readily accessible.

### The Ultra Sound Response

Richard J. Bellucci, M.D. of Manhattan, first called my attention to the existence of an ultra sound response in the eighth nerve of the human brain. Dr. Bellucci had made measurements on many people using a frequency near twenty five thousand cycles-well above the normal range of hearing. He had determined that this ultra sound could be accessed through contact with many parts of the body.

For example, on the tissue near the belly button but no response from the bone or tissue around the nose, chin or front of the head. A response was available also at the mastoid bone. The sound perceived by this stimulation was very high frequency, perhaps around 15,000 cycles.

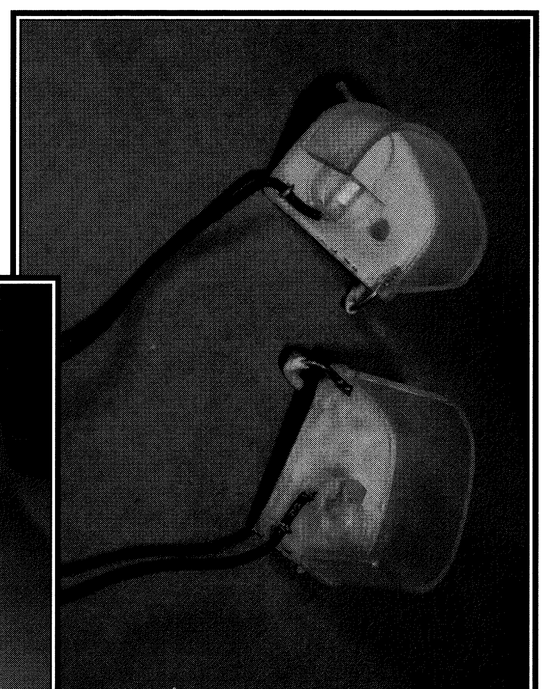
As a result of our discussion, I set out to investigate this ultra sound with the aid of a modern stack of piezo electric transducers with the original Mac 50 watt tube amplifier which was capable of driving the piezo element up to 90,000 cycles per second.

Frequency modulation of the ultra sound source was not noticeable. In fact the same high frequency sound occurred all of the way up to 90,000 cycles. Several different people tested could detect amplitude modulation to about 200 cycles per second.

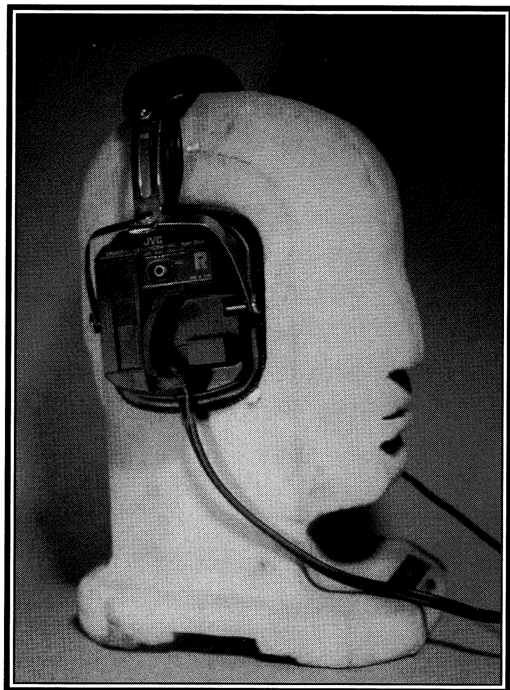
One effect noted was that the mastoid response was reversed. Therefore the left side input seemed to be from the right side rather than the left.

A test on my daughter who was totally deaf in her left ear confirmed that she had not right side mastoid response to ultra sounds but she did have

**Original binaural mikes designed to the ear 1937-style.**



**JVC Model KD-2 stereo cassette tape recorder.**



**JVC Model HM-200E binaural headset.**


**Sony binaural cassette tape recorder Model TCS-430. The space between the two mikes is about 3/4- inch.**

left side sensitivity. Dr. Bellucci had determined that Helen Keller had no ultra sound response, since her eighth nerve was totally disabled.

### Excess Ultra Sound

It is well known that excessive ultra sound can very seriously upset the human nervous system. As a well known example, let me recall the disaster at north American Aviation during early flight tests of its first jet aircraft, the F-86.

*It is well known that excessive ultra sound can very seriously upset the human nervous system.*

During a flight test by the chief test pilot, the F86 turned sideways, and broke up in flight. The aircraft was heavily instrumented by a wireless connection. A very strong ultra sound was noted in the cockpit area and it was concluded that this so disturbed the pilot that he lost control.

The source of the excess ultra sound was the vibration of the metal side panels around the cockpit area. The solution was to laminate two thin panels together with a visco-elastic binder that damped out the vibration through viscous shear of the binder.

My friend Stuart Ballantine determined that one of his employees was very sensitive to 22,000 cycles. So much so that he humped up and ran out of the room when exposed to the 22,000 cycle source. The source was a small whistle used by Ballantine to study the disturbance of certain birds near his lab.

It is very fortunate that ultra sound does not propagate very far in a normal atmosphere, since the ultra sound output from the blades of a jet turbine aircraft engine would create pain and damage to many people. Ground personnel wear ear protective gear, of course, since they are frequently very near these engines.

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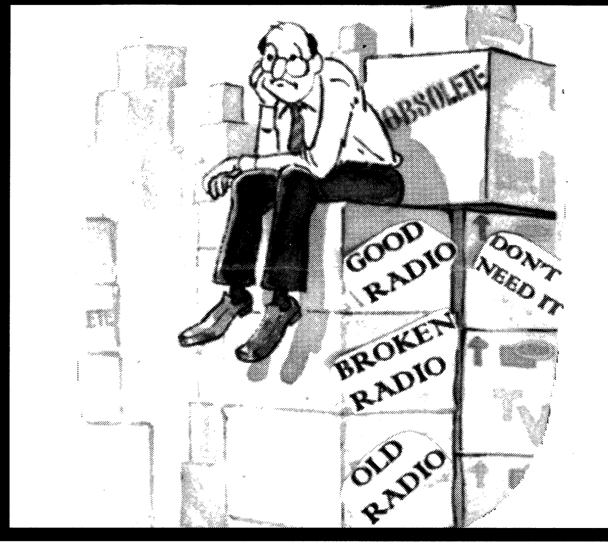


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*Bringing Communication to Education Since 1980*

*By John F. Sevic & John S. Quinn*

# Designing RF Power Amplifiers for 3G Voice Data Systems

As 2.5g third-generation (3G) wireless systems come on line they will be significant information carriers.

Wireless voice systems have pretty much reached maturity. Wireless data transmission, on the other hand, is at its infancy.

Data requires a much wider bandwidth than voice. And if the type and complexity of information that is going to travel the 3G airways is anywhere near its prognostications, power amplifiers will indeed be on the fast track to handling the bandwidth.

## A Brief Look Back

First-generation wireless infrastructure was deployed over a span of nearly ten years. In contrast, third-generation wireless infrastructure will be deployed in a span of three years or less. From the RF power amplifier (PA) perspective, this significant reduction is enabled by several factors, including improved RF design techniques, superior RF semiconductor technology and reliable RF modeling and characterization methods.

Also related to this trend is a transition from system-type companies that contain all essential specialties for infrastructure development in-house, to integration-type companies that specialize in combining value-added features with RF hardware developed by companies specializing in RF components.

This trend started with handset manufacturers and is expected to continue with infrastructure developers. To further accelerate this trend, the design process for high power RF PAs must continue to evolve from a "black-art" into a science. This will enable engineers to focus on design, not on "tweaking," resulting in a significant reduction in the design cycle-time and ultimately in high-yield, first-pass success.

To complement this capability, there must be the opportunity for system integrators to purchase ready-made RF PA products to meet rapidly changing schedules and deployment strategies.

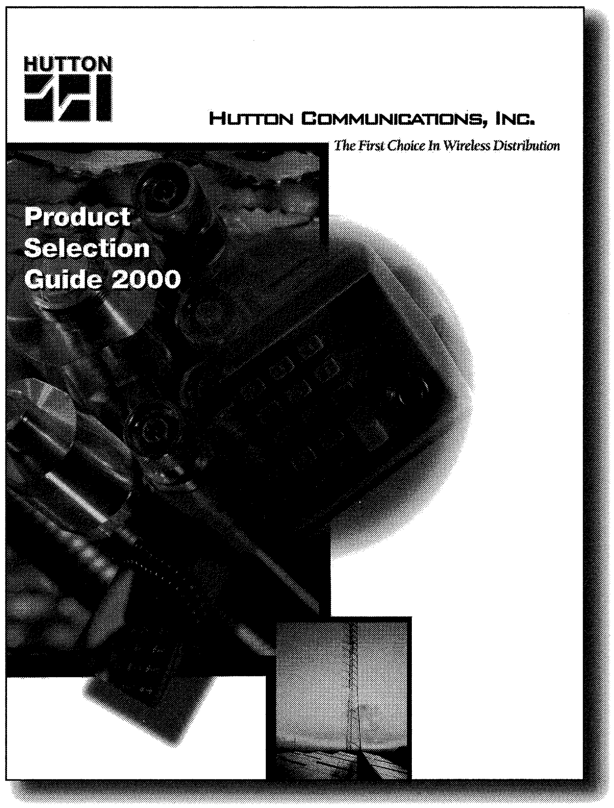
This approach is already well-established in the integrated circuit (IC) world, where customer-owned tooling (COT) and standard products can be purchased from the same foundry. This business model enables design flexibility by its very nature, since the infrastructure integrator can purchase an existing product, have one designed to specification, or use its own in-house design team to implement a design using foundry computer aided design (CAD) tools.

Some recent developments enabling the shift in the high-power RF design community are described in this article, with emphasis on current design and product capabilities.

## Evolution of the Wireless Infrastructure

First-generation wireless infrastructure equipment was an evolution of frequency modulated-(FM) based land-mobile communication equipment, such as police radio systems and private local-area systems. The main difference between the land-mobile PA and the first-generation wireless infrastructure PA architecture was integration of several PAs. Each PA supported one FM carrier with a cavity combiner, providing

# FIND IT HERE!




## Hutton Announces A New Full-Line Catalog For The New Millenium

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## The Sky is No Longer the Limit

Will wireless data truly be significant in third-generation devices? One indicator may be business travelers and the impact they are having on the airlines. The demand for wireless connectivity has led Boeing Aircraft to develop a system that will allow access to the Internet, e-mail, television, news and information in real-time at 40,000 feet and 500 mph.

Boeing's Connexion is a network that will provide high-speed, two-way Internet and live television services in flight. Through this system, two-way, broadband connectivity is delivered directly to airline seats, giving travelers secure access to essentially any form of high data-rate communication. Initially, it will provide two-way broadband data to passengers at 5 Mbp/s receive and 1.5 Mbp/s transmit. The actual bandwidth will be expanded to correspond with technological advancements.

Enabling aircraft to have the wireless connectivity is Boeing's phased array receive and transmit antenna. The 1,500 element antenna, which measures 2' x 3', makes possible bandwidth applications that have been unavailable on mobile platforms in the past. Developed by Boeing in 1986, the antenna provides faster data transmission capability and enhanced response to directional changes by steering signals electronically rather than mechanically. This permits continuous connections between satellites and the aircraft.

There are three basic elements to the service infrastructure. First is the airborne system, which includes airborne antennas, servers, routers and wiring. Next are the corresponding ground systems, which include a network operations center, the associated satellite up and downlink equipment, and a business operation center. The third element is the space system consisting of leased satellite transponders.

The average weight for supporting antenna electronics and network connections to the aircraft seat is approximately 800 pounds for single-aisle planes and 1,200 pounds for twin-aisles. The power requirement is 1,000 watts for the average aircraft.

The hardware required to enable the system is compatible with aircraft manufactured by other companies and will be implemented on mixed fleets. It will also offer multilingual programming and be able to serve every flight passenger simultaneously.

Over the past four years, various portions of the system have been tested on business jets and government planes. In 1996, the Associated Air Center in Dallas installed a Boeing phased array communication antenna on a 757 business jet. With the antenna system on board, the aircraft was able to receive live television, as well as business data, from the EchoStar communications/dish network satellites, and also television broadcasts from the DIRECTV/USSB satellites. More recently in 1999, Boeing outfitted an Air Force EC-130 named "Commando Solo" with the antenna system, making it possible to expand its mission capabilities with live broadband video data reception on-board during flight.

The service is currently available to the private business jet market, with commercial airline installations expected to begin next year. First service will cover travel routes across North America, then will be expanded to other global routes through 2005. Initially, the technology will serve only commercial and private air passengers and government customers, but as the service matures it will extend out to commercial and leisure cruise ships and oil exploration platforms.

–Megan Alderton

simultaneous application of several carriers to a shared antenna.

The next step in the evolution of the PA was extension of the combiner technique for sectorized cells. In these systems, a smaller number of PAs were combined to support one of many antennas co-located on the tower. This provided increased capacity using directional methods. In both of these configurations, class C PAs were adopted for high efficiency.

Second-generation wireless communication systems addressed capacity limitations by adopting digital modulation techniques. Global system for mobile communications (GSM), code division multiple access (CDMA), North American digital cellular (NADC), and personal digital cellular (PDC) each used digital phase modulation, which in some instances resulted in the need for linear amplification due to the time-varying envelope of the signal.

Moreover, system providers were demanding that PA architectures be rapidly configurable to varying traffic loading and arbitrary sectorization, leading to an additional requirement for the ability to amplify several carriers simultaneously. Thus, deployment of second-generation wireless infrastructure led to the demand for linear amplification, although it has not eliminated use of first-generation type architectures.

Demand for wireless data services has led to third-generation wireless communication systems such as enhanced data rates for GSM (EDGE), cdma2000, and universal mobile telecommunication system (UMTS). These systems are being deployed more rapidly than the first- and second-generation systems, and are capable of data-rates of one mega-bit per second (Mbp/s) or higher, supporting voice, data and video. To support the high data-rate, these systems will adopt modulation methods that require ultra-linear amplification. More significantly, rapidly configurable cell-sites will be required (many of which will be required to support multiple wireless standards). The need for linear amplification is expected to become the norm rather than the exception.

### Making High-Power Designs Reliable

The design philosophy for an RF PA is relatively independent of power level, with a few notable exceptions such as heat dissipation and the importance of passive component and combiner losses. What has traditionally made the design of high-power RF PAs difficult, giving it the label "black-art," is the inability to observe and measure significant parameters of interest, such as impedance, directly. Further aggravating the design process is the fact that most of the circuit elements are a significant fraction of the operating wavelength, making measurements even more difficult.

The design philosophy associated with first-generation PAs was based on stub-tuning manual load-pull. With these tuners, the engineer would design a fixture, often with pre-matching, and through iteration, determine the best possible performance for the given requirements. This process was error-prone and slow, but worked for the requirements of the first-generation of PAs. Its major limitations were the inabilities to provide the engineer with the transistor terminating impedances and to provide a picture of performance trade-offs in the gamma-domain. The former limitation made design of impedance matching networks rely on iteration and tweaking, slowing the design process. The latter limitation resulted in uncertainty about the best possible performance trade-off.

In the early 1990s, congruent with the development of second-generation wireless systems, automated load-pull became available from several companies. These systems have, more than any one product, enabled the rapid design of RF PAs. In many ways, automated load-pull is to RF PA design what the HP 8510 is to linear microwave network analysis. Using high-power automated load-pull, the engineer is able to examine performance trade-offs in the source and load gamma-domain for parameters such as power, gain, power amplifier efficiency (PAE), and linearity. Although early load-pull systems were limited to minimum impedances in the neighborhood of 1 W, recent advances in de-embedding techniques and fixture design have permitted this to approach 0.1 W, allowing devices capable of over 100 W at 2 GHz to be fully characterized.

A typical design using load-pull begins with evaluation of several different devices under various bias conditions and frequencies. After the optimum source and load impedances are determined, source and load matching networks are designed using well-established synthesis methods such as the maximally-flat approximation. With the assumption that the transistor sees what it was presented within the test-fixture, the resulting performance will closely match what was observed in the load-pull system. Differences in the width of transmission lines feeding the transistor, even if it presents the same impedance, can cause differences in performance. This issue is aggravated when using a test-fixture and/or transistor package that is substantially different from the target mounting method. For example when designing a power RF module. While load-pull is the most common method for design of high-power RF PAs for infrastructure equipment, it relies on substantial expertise and a large investment in time and opportunity cost to be successful.

The next step in the evolution is deployment of an integrated design environment based on a combination of accurate measurement methods, reliable models of passive and active elements, and an easy-to-use CAD platform. This approach will lead to foundry-based power module designs to meet rapidly changing performance requirements and deployment strategies, while also enabling customers to deploy COT-based designs.

A preliminary version of this design environment is currently being used for the design of custom power modules for digital communications systems (DCS) and personal communications systems (PCS) applications. It consists of a specialized test-fixture that is identical to the mounting method in which the transistor die is used in the module.

For the current 60 W laterally-diffused metal-oxide semiconductor (LDMOS) die technology, the preferred method of mounting embeds the die on a carrier with input and output MOS capacitors and wire-bond arrays giving a prescribed transformation, usually 4:1. The wire-bonds from the MOS capacitors are attached directly to the gate and drain manifolds on the substrate. They are brought out in micro-strip to mate with a custom water-cooled test-fixture connected to a load-pull system. Using well-established de-embedding techniques, the measurement reference-plane is set to include the effects of the pre-matching and the gate and drain manifolds.

The present design environment is based on a hierarchical organization consisting of standard library elements for high-power design.

Typical impedances are in the neighborhood of 2 W, resulting in a well-defined and easy to synthesize impedance. Without pre-matching, typical impedances would be in the neighborhood of 0.5 W, making the design of the matching networks difficult. In a similar fashion, models of passive elements such as chip capacitors, planar couplers, and vias have been created and deployed in an integrated CAD platform.

Using synchronized simulation and layout allows the engineer to determine what the expected performance of the module will be. High-power transistor models with measurement-based pre-matching network models are also available, which allow large-signal simulation of gain, PAE, and adjacent channel power ratio (ACPR). Once the design is frozen, the design rule checker (DRC) is run and the design is taped out to a ceramic fabrication house. This process is nearly identical to what is done in the IC community, resulting in a low-cost, reliable, and fast time-to-market design vehicle for high-power RF.

### A Module Design Flow Using a Power RF Foundry

The present design environment is based on a hierarchical organization consisting of standard library elements for high-power design. This includes transistor die of various gate widths, MOS capacitors, wire-bond arrays, chip components, and planar transmission line elements. Instances embody physical and electrical characteristics, with the latter based on either measured data or analytical models. Using ADS, these attributes are synchronized dynamically to create an integrated design environment, similar to what is done in the IC design community.

To meet the demand for wireless data communications, the EDGE standard is being deployed as an overlay for GSM. This system offers data rates of several hundred kbp/s, but requires linear amplification due to the time-varying envelope. A common power requirement for DCS EDGE is 100 W peak-power spanning the 1.805 GHz to 1.88 GHz frequency region. Using the design kit described, a 100 W module has been designed on a 1,300 x 1,300 mil alumina substrate using LDMOS transistors. The design is based on a branch-line combined architecture with 11 dB of nominal gain and 25% PAE, delivering 20 W average power at rated linearity. The design flow for this module is shown in Figure 1.

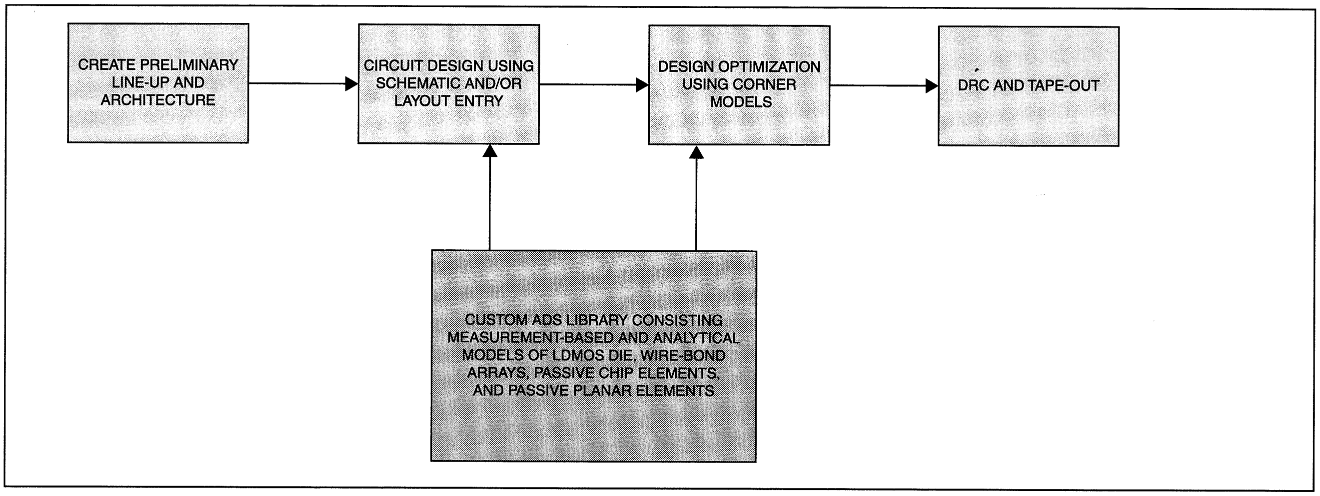


**Figure 1. The design flow.**

The design process for this type of module begins with an estimate of the peak-power requirements and an understanding of the power density of the die. State-of-the-art LDMOS technology currently exhibits 500 mW/mm at DCS/PCS, so in this case, for a quad-combined architecture, each die must be approximately 100 mm in gate width. Settling on a standard 60 W die size, it is placed into a standard carrier with MOS capacitor pre-matching using standard wire-bond arrays (for consistency) and is characterized using load-pull. The resulting impedance data, defined at a robust transverse electromagnetic (TEM) point on a 30 W transmission line (assuming 20 mil alumina), is used for synthesis of the matching networks. As described in the previous section, the carrier, MOS capacitors, manifolds, and substrate of the test-fixture are identical to that used in the module, with a common reference plane. This eliminates any ambiguity in setting reference planes and results in a robust characterization method.

In this example, a two-section match is chosen to give reasonable gain flatness, usually ±0.5 dB. Using industry-specific CAD software and passive models of chip capacitors, matching networks can be designed and simulated while linked directly to the layout. Via models are also included to illustrate their impact on resonance. From this design, all associated assembly documentation is created and the artwork is taped out directly to the ceramic foundry. The overall design process takes less than one month, compared to several months using a standard design procedure with stub tuners, discrete device technology, and conventional PCB layout techniques. More significantly, the ceramic substrate costs less than a single high-power RF package, making this approach competitive with discrete technology.

## Summary

Third-generation wireless infrastructure requires high linearity RF PAs, which are low cost and capable of being deployed rapidly in a variety of design environments. Classical RF PA design was slow, did not provide trade-off information, and required a large investment in technical expertise and hardware. Leveraging design flow models from the IC world enables high-power RF design to be done in an integrated design environment. This results in low-cost RF modules that can be purchased off-the-shelf for standard design applications. For those applications calling for custom designs, an RF module can be done as a customer-owned tooling (COT) design. In either case, due to the low cost of the alumina substrate, with respect to high-power RF packages, an extremely high value-added RF PA results with a cycle time equal to standard discrete design.

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This article originally appeared in the June 2000 issue of RF Design, and is reprinted with permission.

*By Bob Kelly*

# FCC Compliance for Wireless Licensees

The Federal Communications Commission (FCC) issued a Public Notice on February 25, 2000, to restate the commission's position that wireless licensees comply with federally mandated RF compliance regulations before September 1, 2000. Prior to this, the last notice was the Report and Order on October 15, 1997. *SiteSafe's* Bob Kelly sat down with Jerry Ulcek, an Electronics Engineer with the FCC's Radio Frequency Safety Office of Engineering and Technology Division, to discuss what the Public Notice means to licensees, and the penalties that licensees may face due to non-compliance. Here is what he found.

**Will the FCC grant a "grace period" to licensees that are not in compliance?**

***Ulcek:*** We are not anticipating that, no. They have known about the rules since September 1996 when we adopted the guidelines. They became effective October 15 for people that were renewing or putting up a station after October 15.

**Does the RF compliance requirement end on September 1, 2000, or does it become a part of the license renewal process?**

***Ulcek:*** It is an on-going thing. After September 1, if we find any of the licensees are not in compliance with these guidelines, they should have already filed an environmental assessment (EA) with us. If there isn't an EA on file, then they are in violation of our rules. At that point, we can issue sanctions—whether it is fines or suspending licenses.

**The FCC states that an EA is required in cases of non-compliance. What steps can licensees take to remedy non-compliance at sites to avoid filing an EA?**

***Ulcek:*** Every license whether it is a renewal or a new license, asks the environmental question, are you in compliance with section 1.13.07 of the rules? They should have already addressed those issues. If they haven't, the EA is not only going to trigger if they are not compliant with the RF but also if they built in a wetlands and they didn't check with the department of natural resources or if they built in a historical area. It's going to open up a can of worms. They will have to start the whole application process over because of the EA. To remedy it, they had better make sure they have their approvals ahead of time.

**Clarify the phrase 'categorically excluded.'**

***Ulcek:*** That is probably the most misinterpreted phrase or sentence that has ever been put into the FCC Rules. Categorically excluded refers to Table 1 in Section 1.1307 of our Rules and is entitled "Transmitters, Facilities and Operations Subject to Routine Environmental Evaluation." It is also found in Table 2 of Appendix A in OET Bulletin 65. The table lists certain powers that if exceeded and/or heights that are less than 10 meters, would require you to do a routine evaluation. If you are above 10 meters and/or below a certain power level or are not in the table, than it is said you are categorically excluded from having to do a routine evaluation. That does not mean that you are excluded from having to comply with the guidelines. We created the categorical exclusion to try to exclude certain "non-problem" sites such as cellular base stations mounted higher than 10 meters on a monopole from having to do a routine evaluation because their heights and powers will not cause ground level exposure above the public guidelines.

**What responsibilities does a categorically excluded licensee have to other co-located licensees?**

*Ulcek:* They still have an obligation to assist with making sure that the rooftop is in compliance if they are co-located. It boils down to the 5 percent rule. They must find out if they contribute 5 percent or more MPE.

**How can a categorically excluded licensee determine if they are contributing more than 5 percent MPE?**

*Ulcek:* There are multiple ways. You can do calculations, you can do modeling using software or you can take measurements. It is easy if you are the lone person up there and you know what you are putting out. As soon as you are co-located, it is a different ball game because there are multiple antennas involved. Even though your antenna alone might not be the one causing the brunt of the problem, it could be contributing.

**Does the FCC favor software modeling when evaluating cases involving adjacent rooftop facilities?**

*Ulcek:* Modeling is a perfectly acceptable way of determining compliance and MPE levels. But a model or a calculation is no good unless you have the right input. As long as you have the parameters for all of the antennas involved—the frequencies, the channels, the antenna patterns, the input into the antenna—it is probably more effective than actual measurements because they are only a point in time and you may not catch the worst scenario. Modeling is going to overestimate the fields that people generally will be exposed to because it would be a very rare event where you had all channels up, all the time. Modeling may be more accurate as long as the inputs are accurate.

**Should licensees be more or less concerned with liability issues vs. possible penalties imposed by the government?**

*Ulcek:* We are going to be working on the penalties but with all of the liability issues our penalties will be miniscule compared to what someone could sue you for inevitably. So the liability issue is something licensees are going to have to start looking at harder.

**Who is responsible — site managers, building owners or licensees?**

*Ulcek:* From the FCC's perspective, it is the licensee, period.

*By Lynn Meadows*

# Digital Radio Debuts

Call it a radio revolution. With the introduction of two new digital technologies in 2001, consumers soon will have a multitude of digital audio choices available in their car. Receivers for digital satellite radio and digital terrestrial radio should begin trickling into the marketplace in 2001. And if the business plans of three companies come true, the analog radio sound that has been with us since Pittsburgh's KDKA was licensed in the 1920s will be just a fading, fizzing, popping dream.

But consumers can't hear the crystal clear reception of local AM and FM radio and the varied content of national satellite radio with today's radios. Get set for the radio receiver market to heat up.

### Who's Who

In the satellite arena two companies obtained spectrum from the Federal Communications Commission (FCC) in 1997 to provide satellite digital audio radio service (SDARS).

Sirius Satellite Radio and XM Satellite Radio expect to each beam 100 channels of digital music and talk formats from the stars by mid-year 2001 with receivers available immediately. Each will charge $9.95 for their services, which will include never-before-imagined formats and coast-to-coast coverage.

Meanwhile, iBiquity Digital is finalizing development on a technology that will allow earthbound stations the opportunity to go digital. The in-band, on-channel digital audio broadcasting technology (iDAB) allows radio stations to simulcast digital and analog signals on the same frequency. Stations are expected to begin adding digital to their signals in 2001 pending the resolution of certain technological and regulatory hurdles. If they build it, will consumers come?

### Investing in the Technology

Sirius Satellite Radio and XM Satellite Radio are betting big money that consumers want more listening choices in their cars and are willing to pay for them.

XM built the world's largest broadcast facility in Washington D.C. including a room the size of a small gymnasium for live bands. Sirius constructed its national broadcast studio in New York City in Rockefeller Center.

Sirius plans to begin its broadcasts at the end of 2000 or early 2001 provided the launch of its third and final satellite in November is successful. XM hopes to have its two satellites in place and "go national" in the second quarter of 2001. Repeaters on the ground will help both services maintain signal strength in urban areas.

### Multiple Content Choices

For a monthly subscription fee, Sirius and XM say listeners will get as many as 100 channels of formats they have not even imagined. And they will be able to listen to those formats in their cars and trucks from coast to coast.

## Digital Radio Data Services

But wait...there's more. Those zeros and ones zooming through the air with digital sound will also carry data information. Imagine a time when a radio without a screen is considered an antique. Consumers of the future will be accustomed to seeing text and maybe even pictures on their radio receivers.

The in-band, on-channel digital audio broadcasting technology from iBiquity Digital will expand broadcaster horizons significantly. In fact, the ability to stream data may be more beneficial to broadcasting than the crystal clear sound.

Some broadcasters may elect to abandon audible programming in favor of data streaming. At its most basic level, broadcast data sent will be related to the audio programming — artist and title.

Pat Walsh, vice president of wireless data business development for iBiquity, said the wireless data networks formed from digital radio would be similar to cellular networks providing information like traffic, weather, news and entertainment. Add an outgoing link via a cellular phone and radio can be used sell books, music and concert tickets while the consumer is driving.

"What you'll see is less hard coded buttons," said Walsh of future receivers. A common feature would be touch screens that can be updated. He said to watch what cellular manufacturers are developing to get a good idea of where radio design is headed in the near future.

In a study done in May by the Consumer Electronics Association (CEA), 12 percent of the respondents said they subscribed to cable radio — or audio wallpaper as it has been called. But satellite radio is not the same as digital cable radio.

Just as cable introduced channels like the "Arts & Entertainment Network" and "The History Channel," satellite radio will bring formats never heard on terrestrial stations.

XM, for instance, plans to have channels dedicated to each decade of music since the 1940s complete with disc jockeys who talk like they are from the era and news drops from the decade.

The lineup for Sirius includes niche formats like Reggae, Broadway and Children's Entertainment. ASIAONE, an Asian-language broadcaster, will provide programming in Mandarin and Hindi for XM. Both companies will also use programming from well-known sources like National Public Radio, the BBC and Black Entertainment Television.

### Who is Interested?

The CEA Digital Radio study found that 28 percent of the respondents were interested in satellite radio while 33 percent expressed interest in digital radio. The difference was due to the subscription cost.

But the study also found that 44 percent of those consumers who listened primarily to compact discs while driving were interested in satellite radio because content was most appealing to them.

The first generation of satellite radio receivers will receive only one of the services.

The two companies have agreed to develop a unified standard for satellite radios. A combined Sirius/XM satellite, however probably will not be available to buy until 2004 or 2005.

XM Satellite Radio said there will be home products and portable products like CD players with AM/FM/XM manufactured. XM subscription prices for multiple radio distribution packages had not been set.

The receivers will range from $249 to $499 depending on features. Most will display at least some limited information like the name of the channel, title and artist. Alpine, Clarion, Delphi-Delco, Mitsubishi Electronics Automotive America, Motorola, Pioneer and Sharp will manufacture and market XM-capable radios.

Sirius has alliances with Alpine, Audiovox, Clarion, Delphi Delco Electronics, Kenwood, Panasonic, Recoton, Sanyo and Visteon to design and develop receivers for the automotive aftermarket and for installation in new cars.

Car manufacturers agree. BMW, Daimler Chrysler, Dodge, Ford, Jaguar, Jeep, Mazda, Mercedes, and Volvo cars as well as Freightliner and Sterling heavy trucks have all made alliances with Sirius which will begin putting Sirius receivers in new cars in 2001.

General Motors and Honda have each invested $50 million in XM Satellite Radio and XM Radio has a 12-year distribution agreement with General Motors to integrate XM-Ready radios into its vehicles starting in 2001. Freightliner will also begin to offer XM radios in its new model Freightliner, Sterling, American LaFrance trucks and Thomas Built buses beginning in 2001.

Back on the ground...

XM is billing its satellite service as "the next generation of radio," but the older generation of radio is not ready to be left behind. Throughout the world, broadcasters have adopted a technology called Eureka 147 that allows them to broadcast digitally. The technology did not take off in the United States because it requires a different frequency band.

U.S. broadcasters did not want to migrate from the FM band for fear of losing their "brand equity" — all the blood, sweat and tears that make a station be known as "106.9 The Fox" instead of just a classic rock station.

Enter USA Digital Radio and Lucent Digital Radio. The two worked separately to come up with digital radio technologies. Both promoted the idea of in-band, on-channel digital audio broadcasting (iDAB) which will allow broadcasters to add digital to their current frequencies without interfering with the analog signal.

The two companies agreed to merge over the summer and started to combine the best parts of their respective technologies. When that process is finished, the Federal Communications Commission will need to change its rules to allow broadcasters to upgrade their technology. The FCC may also want to adopt a digital radio standard.

Fifteen of the largest radio groups in the country including all those in the top 10 have invested in iBiquity. These groups own roughly 1,983 of the nation's 12,000 radio stations and control about 46 percent of the radio industry's total revenues — a figure higher than $17 billion in 1999. It will cost broadcasters between $30,000 and $200,000 to upgrade and broadcast in digital. Once consumers hear the difference, many "non-traditional after market consumers" may buy digital receivers. The third-generation of satellite receivers is expected to include both digital AM and FM capabilities.

*By Raymond Minichiello*

# Reminiscing about Technology Breakthroughs

In the ever-changing world of wireless, a great romance of the past often occurs following a technological advancement. The magical world of wireless attracted young men as operators aboard ships and land stations who became enchanted with the blasting sound of sparks. This was a fraternity of "Sparks," wireless operators nicknamed for the nature of the transmitters they operated.

## The Allure of Sparks

The joy of the wireless operator was keying his spark transmitter that responded with a fiery dot and dash across the rotary gap that illuminated the radio shack with its blue and white arc, crackling like a lightning bolt producing a fragrance of ozone. The sound fascinated men but panicked many ladies. Thus was the rapture of "Sparks" in his radio shack, his life, his dream fulfilled.

Attempts to minimize the noise of rotary spark gaps in glass enclosures were hardly successful. A remote installation of the rotary gap in a closet like room hardly dampened the extraordinary shriek of the arc. But, the arc was music to "Sparks" the operator. Listening to the arc as he keyed, he monitored his fist and developed his swing. Sparks was in command, he reigned supreme as the man behind the wheel of the rotary arc.

But all this became a glory of the past as the contributions of DeForest and Fleming together with that of companies such as RCA, GE and Western Electric rapidly developed "radio tubes." Thus the birth of the oscillators containing tubes in many circuitry forms, Heising, Tuned Plate Tuned Grid, Hartley, Colpitts and foremost of the period, the self-rectified self-excited push-pull oscillator. This design engineered for inclusion of the new UV-RCA 204-A tubes was a masterful development that quickly elevated wireless technology to a new plateau.

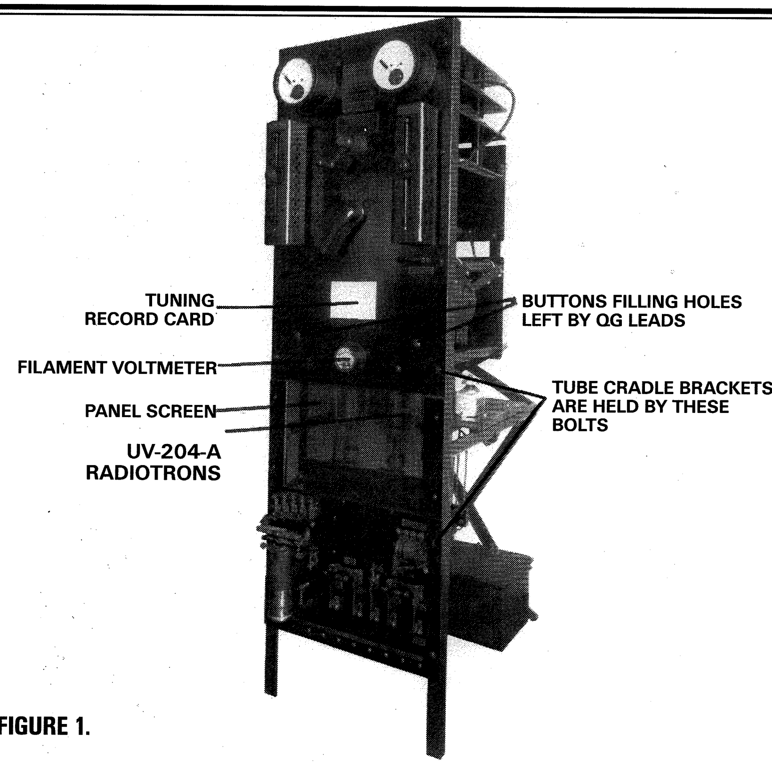
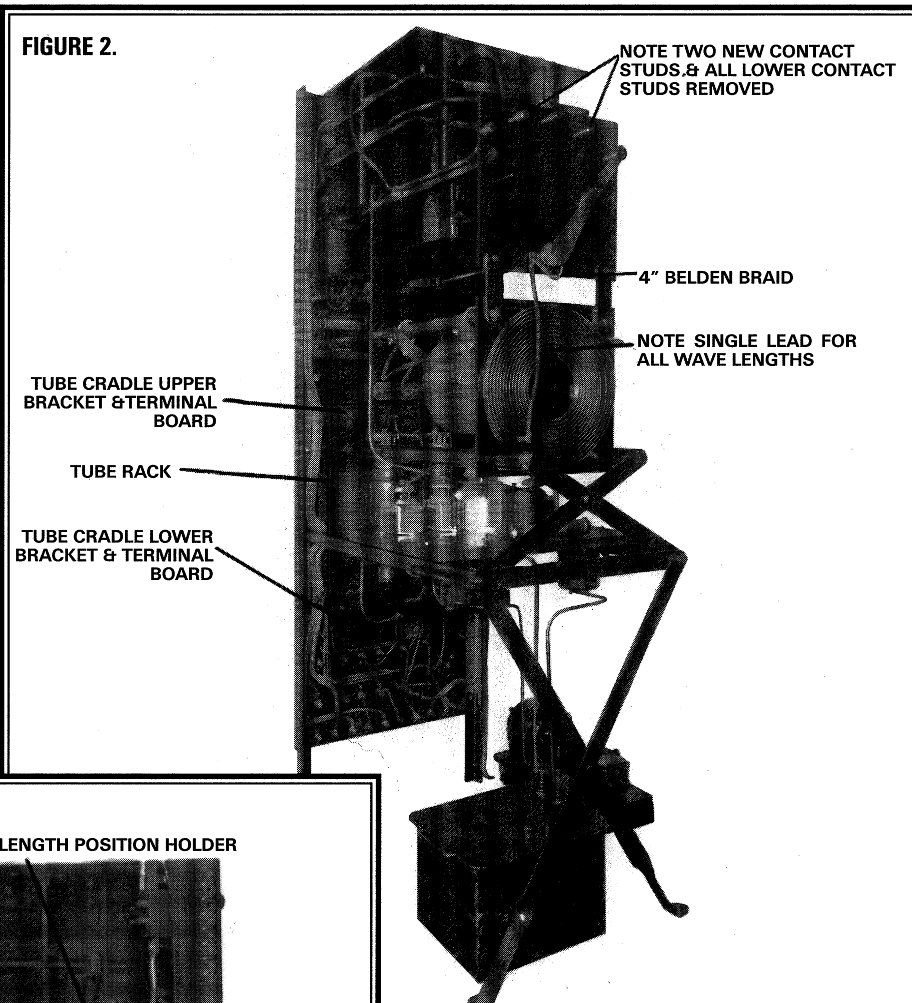



**FIGURE 1.**

## The Changing Landscape

By 1919, spark transmitters aboard ships and land stations numbered in many thousands. The need for new installations was growing rapidly. The American Marconi Company, essentially a monopoly of American wireless communications, entered into an agreement with General Electric Company in which the controlling shares of Marconi stock was purchased by General Electric Company for $3.5 million. The United States Government recognizing the potential of radio communications, authorized the merger of patents by General Electric, AT&T and Westinghouse. Thus was born the Radio Corporation of America (RCA) in October 1919. David Sarnoff, a Marconi employee was named its commercial manager.

**FIGURE 2.**



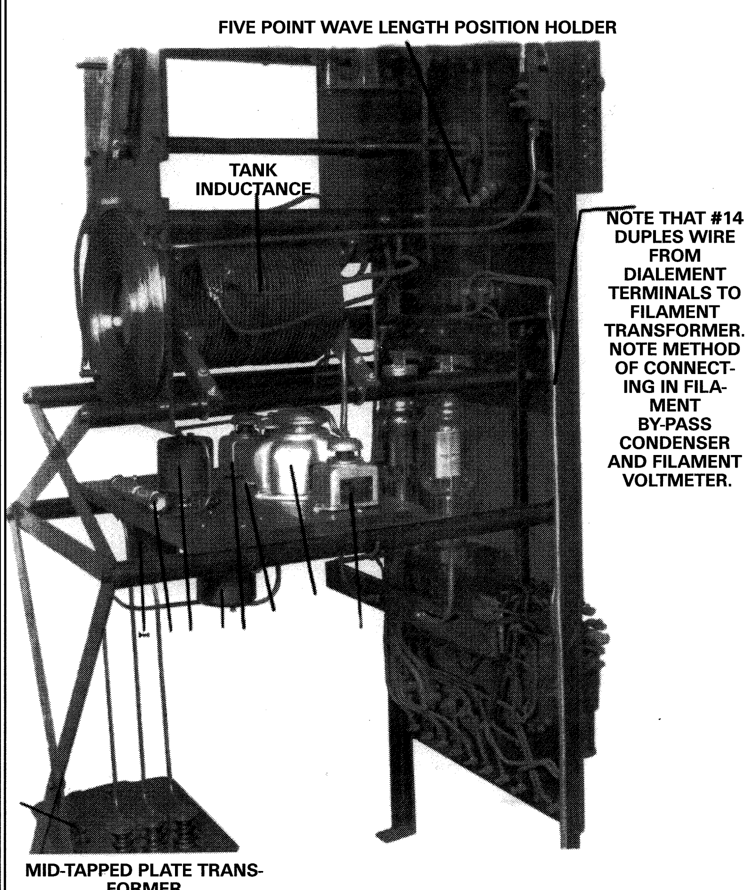




**FIGURE 3.**

The growing demand for home entertainment products in the early twenties occupied RCA in the manufacture of radio receivers, radio tubes, broadcast equipment and included the purchase of the Victor Company, then prominent in the recording industry. RCA while concentrating on the entertainment market continued to provide the Type P-8 spark transmitter, through its Radiomarine Division, but built by the General Electric Company,

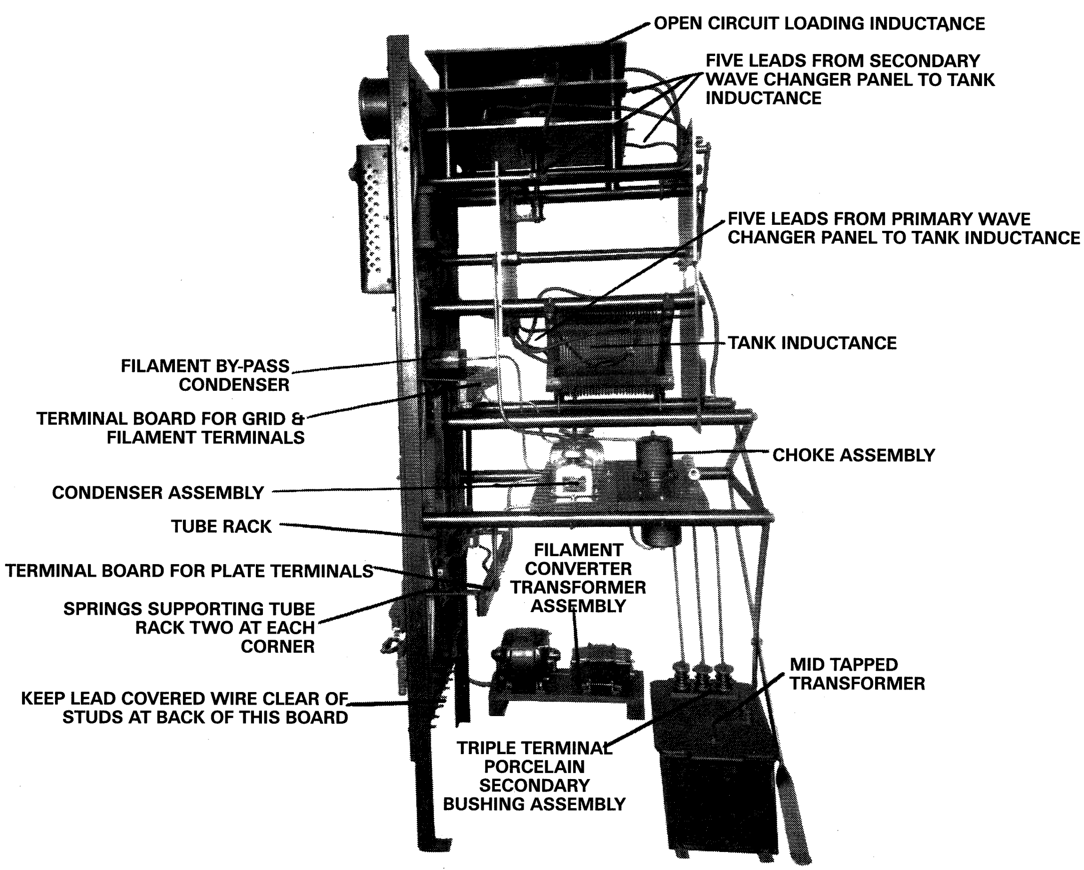
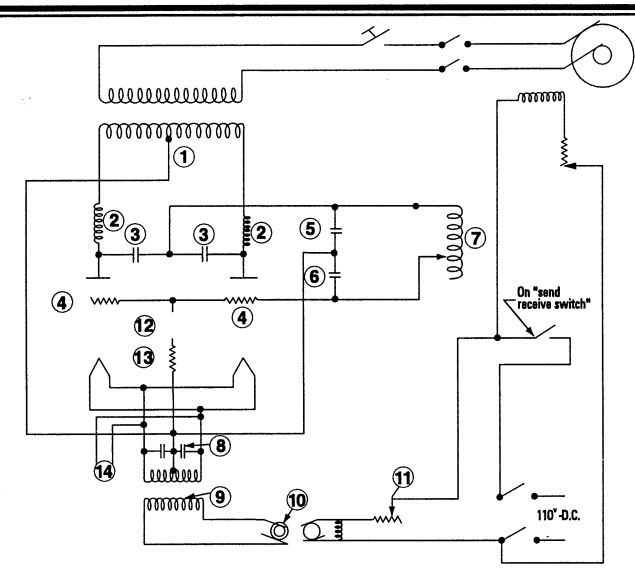



**FIGURE 4.**




1. High voltage power transformer
2. Plate choke
3. Output coupling capacitor
4. Tube, RCA UV-204-A
5. Plate excitation capacitor
6. Grid excitation capacitor
7. Tank coil
8. Filament by-pass capacitor
9. Filament transformer
10. Filament converter
11. Filament rheostat
12. Grid leak choke
13. Grid leak
14. Filament voltmeter

**FIGURE 5 Schematic of self-exited, self-rectified, push-pull oscillator.**

Research laboratory in Schenectady, NY.

General Electric Company, always quick to recognize an available market, offered the field retrofit of all installed Model P-8 spark transmitters by simply removing the rotary arc generator. It installed in its place a pair of new RCA UV-204-A tubes, wired in push-pull as a self excited oscillator, self-rectified, together with other minor component changes. To further satisfy the market need, General Electric produced the new Model P-8, transmitters identical to the units modified in the field.

The P-8 transmitter was of open frame construction as shown in figure 1, following the modification. The essential changes included the removal of the rotary arc mechanism and installation of the two RCA UV-204-A tubes wired in push-pull and replacement of the power transformer with one having a center tapped secondary,

Lee DeForest and his invention of the
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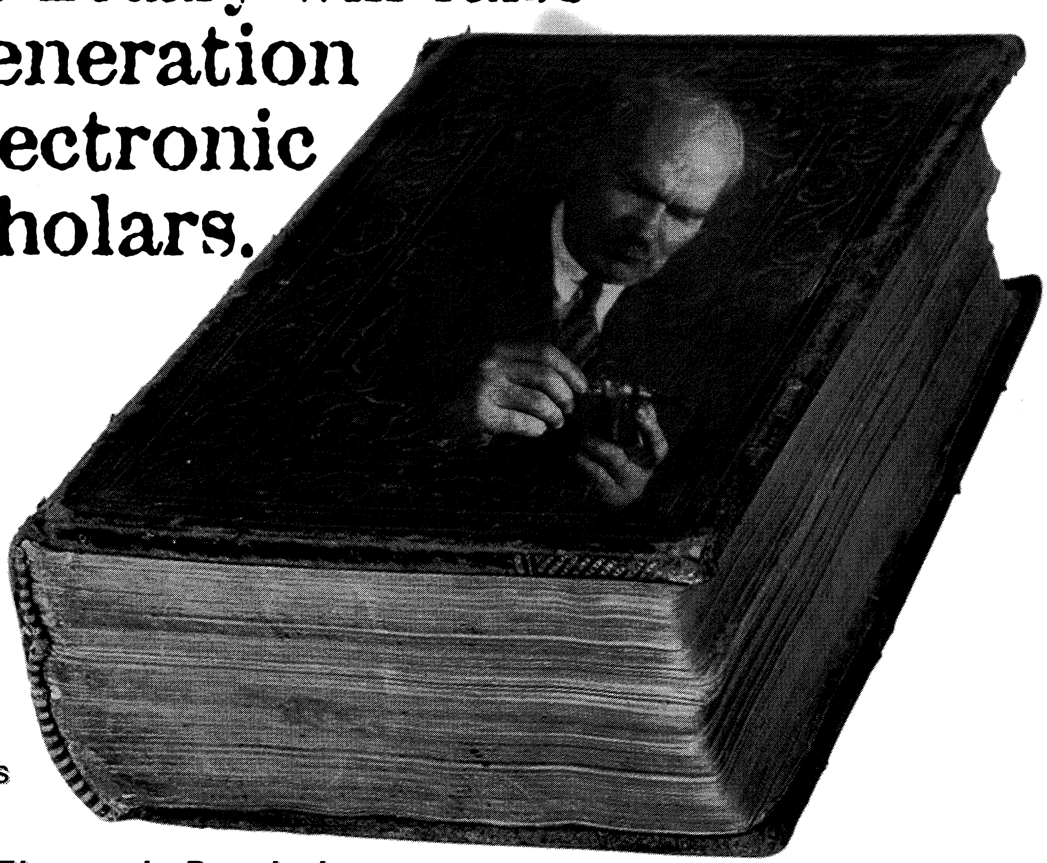

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**FIGURE 6. Paul Goodley at the VLF loop antenna aboard the Marconi yacht "Electra."**

fed directly from the motor driven 500 cycle AC voltage generator.

In Figure 2 the 2 KW power transformer can be seen at the base of the transmitter. Figure 3 is a more detailed view following the conversion illustrating the antenna-coupling coil at the left of the tank coil. Installation of a five position switch allowed tapping the tank coil for operation on five different frequencies, a new feature compared to the broad single frequency restriction of the spark transmitter. Further the tubed transmitter generated a sharp, clean signal tone modulated by the 500 cycle motor generator.

In self-rectifying circuits, the AC voltage from the secondary of the center-tapped power transformer is applied alternately directly to the plates of the oscillator tubes. During the positive cycle, the output voltage will be developed whereas during the negative half cycle, the tube is inoperative. As in a full wave rectifier, the plates are supplied with AC voltage alternately, 180 degrees out of phase. Because the circuitry contains a high tank inductance, the current drawn by each tube is fairly constant.

However, the 500 cycle generator introduced AM modulation and any imbalance of the tubed circuitry contributed a bit of phase modulation, thus by combination of the two, there was introduction of prominent side bands. But the modulated carrier delivered a melodious tone signal then known as modulated continuous wave (MCW) that sent the Department of Commerce scurrying to classify the new mode of transmission.

But alas, after the conversion, the wireless operator lost his identity as the noise generator nor could he monitor his sending fist in the absence of the shrieking arc. The UV-204-A although designed in 1920, has until today enjoyed continued favor in the design of broadcast, commercial and radio amateur transmitters as final amplifiers. A pair of 204-A tubes as a self-rectified amplifier in C.W. circuitry was commonly used in the early twenties negating the need for a filter section of the power supply. The Radio Club of America participating in the 1BCG successful 150-meter transatlantic tests by club member Paul Godley in 1921, utilized a pair of UV-204-A tubes as final amplifiers at the Greenwich, CT, transmitter site.

Guglielmo Marconi quick to recognize the benefits of high-frequency (HF) over very-low frequency (VLF), switched to the UV-204-A in new transmitters in his European operations as he vacated the lower frequencies and spark. Confidence in the higher frequencies by Marconi was enhanced at his meeting with Paul Godley on the yacht, "Elettra." Figure 6 shows Godley who described his successful transatlantic tests.

### The End of the Spark

The romantic days of the rotary-arc transmitter were over. No more would men be attracted to and fascinated by the roar of the arc. The women who once cringed at the sound of the arc were pleased at the elimination of the "awful noise." In the quietness of the radio shack, the "Spark" became more conscious of his sending fist as the new transmitter produced a crisp sharp tone. Operators learned to cut the input switch to the motor generator during the last sentence of a transmission. This caused the tone frequency of the modulated dots and dashed to decrease and fade away as the motor generator R.P.M. slowed down and as they held the key down for the last letter of "SK." The technique became known as "musical English."

The professionals soon learned to manipulate the power switch on and off during an entire transmission to produce a singsong of dots and dashes. Thus, the birth of vacuum tubes and new circuit technology wiped out the spark transmitter that for twenty years had reached a peak of development as the rotary arc, quenched gaps, staggered rotary gaps and too, the fifty-ton 200 KW Alexanderson alternator, the last two manufactured by General Electric in 1921.

The transition from sparks to the more sophisticated technology of oscillators and amplifiers employing the vacuum tube such as the new 203 and the UV-204-A occurred almost overnight. It was a shock to the wireless (radio) industry including the fraternity of "Sparks," rendering all of their learning of arc generators just a memory. In the business of wireless communications, revolutionary developments in technology will continue to profoundly affect our daily living, leaving behind lots of time to relate tales of "how it once was."

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***SOFTWARE DEVELOPMENT MANAGEMENT, EMBEDDED CONTROLLERS***

# Ad Index

# The Radio Club of America, Inc.

Founded 1909

WORLD'S FIRST RADIO COMMUNICATION SOCIETY

## APPLICATION FOR MEMBERSHIP

Date: ______________________

TO: **THE EXECUTIVE COMMITTEE**

I hereby apply for ☐ Regular ☐ Retired ☐ Student (please check one) membership in THE RADIO CLUB OF AMERICA INC. and certify that I meet the requirement for the grade selected. I further agree that, if elected, I will be governed by the Club's Constitution and By-Laws as long as I continue to be a Member.

______________________________

Signature

Full Name: ______________________________________________
(LAST) (FIRST) (INITIAL) (CURRENT AMATEUR CALL)

Home Address: ______________________________________________
(STREET) (The above information is used for mailings and your membership directory listing)

______________________________________________
(CITY) (STATE) (ZIP CODE)

Business Address: ______________________________________________
(ORGANIZATION) (DIVISION)

______________________________________________
(STREET) (CITY) (STATE) (ZIP CODE)

Telephones: Home ____________ E-Mail ____________ Fax ____________

Business ____________ Ext. ______ E-Mail ____________ Fax ____________

Birthplace: ____________ Date of Birth: ____________

Education and memberships in other clubs and societies: ______________________

______________________________________________

In what particular branch of the communications art are you most interested? ______________

Present occupation ______________________________________________

In what year did you become interested in electronic communications? ______________

Previous experience (indicate approximate dates): ______________________
(a current resume may be attached to the application)

______________________________________________

______________________________________________

______________________________________________

Please list the name of a member to whom you are personally known and who will sponsor you.

Sponsor: ______________________________________________

Mail this application to The Radio Club of America, Inc., 244 Broad Street, Red Bank, NJ 07701 (732-842-5070), with applicable total due at initiation as indicated on reverse of form. All monies to be issued in U.S. funds, drawn on a U.S. bank. International money orders and traveler's checks are accepted in U.S. funds, payable in the U.S. Checks should be made payable to **The Radio Club of America, Inc.**

The Radio Club of America was founded in 1909 by a group of the industry's pioneers, and is the first active electronics organization in the world. Its roster of members is a world-wide Who's Who that includes many who founded and built the radio industry.

The Club's objectives include promoting cooperation among individuals interested in electronic communications and in preserving its history. The Club administers its own Grants-In-Aid fund to provide educational scholarships from tax-deductible contributions of the Club's members and business organizations.

The Club publishes and distributes its PROCEEDINGS twice a year.

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## ENTRANCE FEE AND DUES

| Membership Category | Annual Dues Rate | 3-Year Dues Rate | Initiation Fee | *Total Due At Initiation |
|---|---|---|---|---|
| Regular | $35 | $95 | $40 | $135 (Includes 3-yr's dues) |
| Retired | $20 | $55 | $25 | $ 80 (Includes 3-yr's dues) |
| Student | $15 | n/a | $ 7 | $ 22 (Includes 1-yr's dues) |

**REGULAR** member is a member not qualified for **RETIRED** or **STUDENT** status

**RETIRED** member is at least 65 years of age and fully retired.

**STUDENT** member is a full-time student at an accredited academic institution.

*For Non-U.S. Mailing Address please add $45 surcharge ($15 per year of dues) to Total Due At Initiaion

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Recommendation of sponsor: (optional)

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Sponsor Signature: ______________________________

Date: ______________________________

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**FOR OFFICIAL USE** **REV-040198**

Date Application received: ____________________

Date and Amount of Dues Received: ____________________

Admitted to Membership: ____________________

Membership Certificate and Pin issued on: ____________________