The Signal

OFFICIAL MAGAZINE OF THE COLLINS COLLECTORS ASSOCIATION * Q4 2013 Anniversary Issue *

Rockwell Collins - 1971 to Date -

Pro-Mark™ KWM-380 transceiver

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Collins Collectors Association

The Signal Magazine

OFFICIAL JOURNAL OF THE COLLINS COLLECTORSASSOCIATION

Issue Number Seventy Two - Forth Quarter 2013

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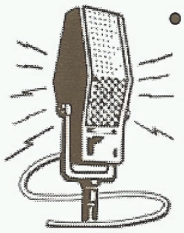

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Editor Bill Carns, N7OTQ
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- Holiday Greetings -

To Our Membership & the People of Rockwell Collins

The membership of the Collins Collectors Association - and its management team - would like to take this opportunity to say "Seasons Greetings and a Very Happy New Year" to all of the employees of Collins Radio and the Rockwell Collins Corporation.

We hope that all of you have a wonderful and safe holiday season and that your 2014 is rewarding and fruitful.

This issue is the last (post Rockwell) issue of the four part series that we hope has served to document some of the great history of Collins and Rockwell Collins. We hope that you have enjoyed the stories as much as we have enjoyed working with the many retired and working Collins, and Rockwell Collins, employees.

It has truly been a privilege working with all of you, and all of us have, in one form or another, expressed our pleasure in getting to know many of you for the first time, and working with you during the research that led to some of these stories. They are your stories, and you should be proud of them and your history.

This issue particularly is dedicated to all of those that "weathered the storm" and then proceeded to help make the turn-around of Collins Radio a success. It is also dedicated to the Rockwell management who had the vision and perceptiveness to see the inherent value in the heritage and ethic of the Collins Radio Company while it was struggling.

This dedication should also rightfully extend to Arthur Collins. Without his vision, leadership and enthusiastic pursuit of excellence, the company would have never arrived at the 1972 juncture with Rockwell.

As it says in the Post Rockwell article, the Collins spirit prevailed and fate smiled on a great company. May that continue!

the **CCA Board of Directors**

A Quick Look in This Issue

FROM THE STAFF

by Bill Carns, N7OTQ & Don Jackson, W5QN

From the Desks of N7OTQ & W5QN . . . .

What a year! What started out as a vision (To tell the Collins Radio story), turned out to be a wonderful and educational journey.

When we here at the *Signal Magazine*, and the CCA Board of Directors, discussed doing four anniversary quarterly issues that focused on the four eras of Collins history, the idea had yet to take solid form. When we closed out 2012, the *Signal Magazine* was running 24 pages, and we all were pretty happy with the membership's acceptance of the content and the impact of the work.

All of us, including the editors, envisioned a result that was similar in size, but with a more (for the 80th anniversary year) standard format and content . . . . content that would tell the Collins Radio story of the era, the equipment, the people, and the business.

Little did we know that, by making that decision on content - and by aiming more generally at telling the story adequately, that we had just relinquished control over the magazine, and turned that control over to the "story" itself.

Following the Q1 Prewar Issue (which quickly rose to contain 32 pages), we realized that we had lost control. Some good discussion, and reminders about budget and workload, resulted in a decision by the board to "invest" a bit in the magazine for 2013 and continue to tell the story as it should be told. Fortunately, the CCA was, and is, in a financial position to invest some funds in the effort. That is one of the things that we hold reserves for. In 2014, the magazine will return to its normal size, and the budget will again be balanced.

Something else happened along the way too……and this could not make us any happier. When the efforts to tell the story of Collins' history started, there was a small but enthusiastic core of people that took on the job of doing the research required to get the facts and stories straight and documented. We all soon realized that, not only was there this intriguing job to do (almost like a puzzle to solve), but we – the research team – were going to be learning a whole lot (always fun). We also realized that we were going to need a LOT of help.

We reached out to a multitude of retirees and current employees who had participated in the story – folks that had actually lived it - or at least folks that knew first hand stories. These people, in many cases, were retired, had moved from Cedar Rapids, and were in the far corners of the country. Many had lost touch with their peers of years ago.

Then the miracle occurred. These people – without exception – became excited about recovering, and telling, the history of the company and its people. In some cases their memories were foggy and only partial stories emerged. In many of those cases, these people reached out to talk with others that were involved. More names emerged. Slowly, but surely, the number of contributors multiplied. But….more importantly, those folks that had lost touch with peers started talking on the phone, and then visiting. The circle widened and multiplied. The social impact of doing the research was astonishing.

We can only smile at the fact that the magazine and our efforts here have served somewhat as a catalyst - and made phones and doorbells ring. We had no idea what we were starting when we began.

All of us can't thank all of you enough for the joy of working with quality people and for the privilege of sharing in your story . . . As well as for the opportunity to learn more about a wonderful company. Never have I seen such a conglomeration of quality people and families. It is heart-warming.

Looking at the experience from another perspective, the last 12 months research also speaks volumes about Arthur Collins. He not only built and led a culture that fostered technical and quality excellence, but he had a unique ability to find and hire (and then motivate) quality people. . . . . Quality family oriented people!

Like we said….The vision has become a journey, and we are pleased to say that it is not over. As a result of the people met, and the stories unfolding, we will all continue to share this journey for the rest of our lives.

For the entire staff of the *Signal Magazine* and the CCA management, We would like to wish everyone a safe and very joyous holiday season.

Our Best 73s - Bill, K0CXX/N7OTQ & Don, W5QN

email: wcarns@austin.rr.com

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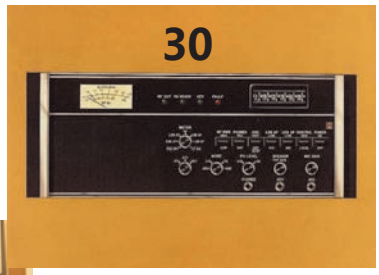

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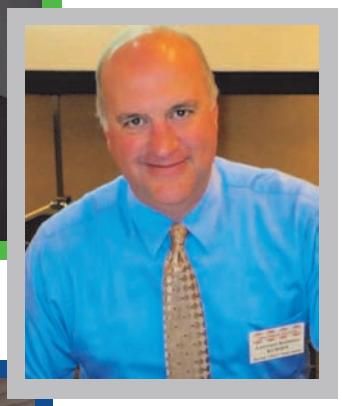
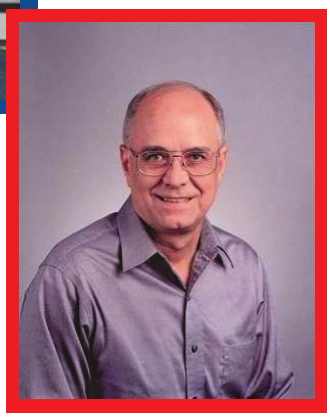
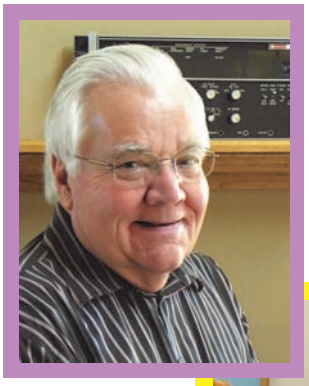






Loney Duncan, W0GZV
"Fifty One Years of TACAMO" *page 10*

Loney joined Collins Radio, Cedar Rapids, in 1957. He served in Engineering Development & Line Management before becoming Division Director of HF Equip. & High Power Transmitters. After moving to Dallas in 1969 in this capacity, he was promoted to VP, Electronic Technologies & Processes reporting to R. Cattoi, Sr. VP of Engineering. He served under Bob Wilson and then Don Beall for many years – retiring in 1998. He is an avid Collins preservationist.

Lawrence Robinson, KC0ODK
"Avionics—Then & Now" *page 20*

Lawrence is currently the Curator of the Rockwell Collins Museum. He also is a Sr. Engineering Manager in the Government Systems Group at Rockwell Collins. His experience includes spending most of 2004 at Boeing in Seattle, Washington representing the Rockwell Collins Corporation on the Joint Development Phase Team for the 787 Dreamliner.

Scott Johnson, W7SVJ
"UHF at Collins", *page 24*

Scott has written for the *Signal Magazine* in the past and is very "Welcome Back". He is a significant collector of Collins avionics and military boxes, and operates a prolifa of this equipment. Professionally, he is an engineer, but he has also run FAA approved avionics repair facilities for the Air Force and for his own business. In addition, he is a Certified C-130 flight Engineer and a pilot, so he brings a very interesting perspective to this subject.

Rod Blocksome, K0DAS
"HF-80 . . . My Story", *pg 30*

Rod retired from Rockwell Collins engineering where he had worked as project lead on several HF-80 PAs. As past curator of the Rockwell Collins Museum, he is passionate about all things Collins. Here he shares his personal experiences with the HF-80 project as well as those times at Collins. He is still very active with the HF-80 systems in use today - as well as with RC Museum related projects.

Dave Berner, Retired Rockwell Collins
"Concept to Market, HF-80 & Casper", *pg 36*

Dave Berner, BSEE Communications, served Collins, and Rockwell Collins, for 34 years before retiring in 1997. He was the Product Line Manager for the URG I & URG II and also responsible for planning the HF-80 program and CASPER, the code name for the KWM/HF-380 and HF-280 series development. He lives with his wife Pat in Saint Louis, Missouri where he is very active with the Lutheran Church. Welcome to the *Signal* Dave!

Don Jackson, W5QN
"30L-1 Instability?" *page 28*

Don Jackson shares some of his technical knowledge and drills down on one of the mysteries of our famous little amp. His work always reflects his thoroughness.

The Rockwell Effect - Quieting Troubled Waters

by Bill Carns, N7OTQ

Prolog

The story of the Post Rockwell era of the Collins Radio Company is a story that covers 40 years and the clock is still ticking – and very strongly ticking we must observe. This is a story that many of you have lived, and that many more of you have read about already. It is a fascinating story of survival and triumph – yes, and smiling fate - and has been well told by several excellent books. Both the Rockwell Collins "75 Years of Innovation" book by Braband and Smith (published by WDG Communications), and Ben Stearns' wonderful book, Arthur Collins *Radio Wizard* published in 2002, tell this story quite well. They are highly recommended and it would serve no purpose to echo this work here.

What is worth revisiting is part of the story. So let's take a look at the portion that has to do with the remarkable turn-around of a troubled company that contained a wealth of resources.

Everyone loves a story with a happy ending – particularly if that story is about people. In fact, the story worth delving into here is just that. It is the tale, not only of a few very talented managers that just happened to be at the right place at the right time, but also a story about all of the employees at Collins Radio. During a time when moral could have collapsed, and when – very easily – disappointed customers and poor performance could have aggravated an already very tenuous situation, this did not happen.

You already can guess the ending, I am sure. There are some that would argue that the story has yet to end, and in a good sense that is true. Rockwell Collins is alive and well and growing and reporting good earnings – and long may it last.

But let's go back to the perspective (the part of the story) that does have an ending. When we left off last quarter, and the Collins Radio Company was awash in debt and having trouble making payroll, it was not a good time. Those that were there, and those that watched, or came soon after and heard the stories, usually use the words "Painful", "Difficult" and "Desperate".

Pain

You remember from last quarter that *Total Reported Liabilities* as a percent of Sales had started to rise rapidly in 1967. These liabilities had long been higher than "well performing" companies – even in the 1950s and '60s. Read the conclusion of the Q3 *Signal* article on the Post War Collins Radio performance (p15). Then, with the essentially flat sales in 1968 and dramatic drop in sales in 1969 and 1970, this *Liabilities vs. Sales* Index had suddenly exploded and become the glaring sign of eminent doom. Starting in 1968, and more so in 1969, Collins had trouble meeting their obligations and great difficulty even making payroll.

The "pain" started in earnest in 1969. In response to these financial woes, and still trying to protect his "New Markets", and the Computing side of the company, Art Collins and the management team at Collins Radio was forced to reduce payroll at an alarming rate. These layoffs, sometimes getting as deep as 30% in one cut in some engineering groups, would go on until just after the first financial injection ultimately brought to the picture by North American Rockwell.

When Collins Radio went into the 1969 fiscal year, they had a little over 23,000 employees. By 1971, the time that Rockwell (November 23, 1971) was invested and involved in the management, this number was down to 14,500 and falling rapidly.

To keep this in perspective, the total sales had fallen from $447M in 1968 to $250M in 1972. This is a reduction in sales of 44% in 4 years. In response, both pre and post-merger, the headcount was cut by almost an even 50% over the same four years. Like the people that lived it say…. painful and desperate times.

It is very interesting to note, that with all that disruption, and all of the obvious potential morale issues that could, and in some case did, come up, that programs like TACAMO (See Loney Duncan's comments about this period in his article in this issue) continued to meet objectives and the walls did not fall in. That says quite a bit about the people and the culture that was in place at the time.

But, we are getting the cart before the horse. Let's refocus our attention on the period right before, and through, what is called one of the most astonishing turnarounds in the annuls US business mergers. History could have taken many paths then.. Easily, the entity "Collins" could have disappeared - been absorbed into Rockwell - never to be seen again. The fact that it remained physically, and in many ways culturally, intact is what makes the history so fascinating.

A great deal has been said about how Bob Wilson turned the company around in just over a year. Facts are facts - and that did happen, but there was a story behind the story. Fortune smiled and a good culture also prevailed.

When Collins Radio got in real trouble, the sharks had begun circling. Ross Perot, TRW, Hughes, and surely others, saw opportunity. In one form or another, they saw the opportunity to make money. Rockwell Collins was no different. One can only speculate on how that would have played out with the other potential investors, but some of the typical scenarios are not pretty. Often companies are acquired, pulled apart and sold for pieces, and nothing remains but the bones.

Fortune Smiles

North American Rockwell prevailed as a suitor. More importantly, they had prevailed, not only because they came at the right time with a good offer, but because Arthur Collins and his management team were comfortable with the approach that Rockwell was taking.

Rockwell had clearly recognized the intrinsic value in the culture of quality and technology excellence that Arthur Collins had built at Collins Radio. They also realized that Collins Radio was the quality leader in almost every market that they had chosen to penetrate. And, they knew that it was the people of Collins Radio that had made that all a reality. This would have a lot to do with how the turnaround attempt would be managed and how the company would be impacted.

In 1969, Collins Radio was organized functionally. This is typical of a "technology" oriented company, and is more common in startups and single play companies that focus on one market area. It is not particularly common, or successful, in $400M companies that are serving multiple markets and are 35 years old.

Senior Management at Collins in 1969 included A.A. Collins, - President, Wm. W. Roodhouse, - Exec. V.P., L. Morgan Craft - Sr. V.P. (Manufacturing & Engineering), T. A. Campobasso – V.P. Marketing (Telecommunications & Government) and E. A. Williams, Sr. V.P. (Control & Finance).

In addition, there were four other V.P. level officers with responsibility for facilities (International, Cedar Rapids, Dallas & Newport Beach), four more with control responsibilities (Counsel, Counsel & Secretary, Controller and Treasurer) and six more V.P.s with responsibilities defined as "Engineering and Sciences" – but identified by markets.

Then there were four more V.P.s (Marketing, International Marketing, Procurement and Industrial Relations). Bottom line, this was a highly matrixed organization.

In all, there were 23 officers (including Arthur) running the company and they were organized into a mix of categories ranging from location to functional description. Reporting to these 23 officers, there were 8 more levels of employees that were then forced to matrix with each other when they addressed a particular market. This was truly a "deep" organization with a lot of layers between the leaders and the "troops". Only within the marketing organization was there a semblance of real customer orientation.

In mid-May of 1971, after fending off what amounted to a hostile takeover attempt from Ross Perot, and then flirting briefly with first Honeywell followed by TRW, Collins sat down at the table with representatives from North American Rockwell Corporation. Two weeks later they had an agreement signed that would facilitate the injection of $35M cash into the Collins economy in return for a controlling number of Rockwell members on the Collins Radio Board of Directors. This agreement was approved by the Collins shareholders August of 1971 and was completed by early September. Art had lost the company.

Remember that fiscal year 1971 (ended Aug. 3, 1971) had shown a loss of $46.6M on sales of $287M. Because of the strong respect for the Collins culture within the Rockwell management, particularly by Willard Rockwell, Chairman of the Board, the early plan was to leave the management of Collins Radio relatively intact while the performance issues were addressed. But, when the fiscal Q1 1972 results came in (another $8M loss in spite of the economy turning more positive), Rockwell made the decision to install Robert C. Wilson as the President of Collins Radio and move Arthur into an advisory role – remaining on the Board. This change occurred November 23, 1971. Dissatisfied with this advisor role, in January of 1972, Art Collins resigned from the Collins Radio Board. See A. A. Collins Inset.

R. Wilson

Bob Wilson was, at the time, the head of the Commercial Products Group of North American Rockwell. His experience included 25 years at General Electric where he rose from a ground level entry position before WW II, to V.P. of Consumer Electronics following being V.P of Industrial Automation. In 1969, he left G.E. feeling he would never make CEO there – his ambition - and joined North American Rockwell as the Director of the Commercial Products group.

He quickly developed a solid record of financial improvement and successes. It was in this V. P. position that he was involved with Willard Rockwell in the original decision to invest in Collins Radio. Wilson was given the President and CEO position at Collins because of his original strong opinions about the value of the Collins Radio culture (and its market and product strengths) as well as because of his sound financial management reputation. The decision was well founded.

Bob did not waste any time getting. Rockwell's investment in Collins, and the strong outgoing personality of Wilson, soon turned the reluctant banking community's heads and allowed Wilson to restructure the mounting debt that came along with Collins, as well as pay some of it down. This gave Wilson the breathing room that he needed. He also wrote down the bloated inventory value that bore the weight of the excessive *carried forward* R&D charges. This valuation also was excessive in light of the reduced projected sales levels.

The Partnership

Wilson quickly also turned to a resource that would prove very valuable - and that is part of the "fortune smiles" aspect of the story. Sitting in another division of Rockwell at the the time, was one Don Beall. Don was the CFO of the Autonetics Division of North American Rockwell. More importantly he had a strong grasp of the importance of P&L control and visibility in an organization.

Almost immediately, Bob (and Don) made some critical changes in the accounting system of Collins Radio. Previously R&D, and some development engineering costs, were carried forward pending sales. This made for inflated inventory costs and unpredictable margins. This was changed to the more conventional method where R&D and development costs are expensed at the time of occurrence. Strict cost con-

Arthur A. Collins - retired from Collins Radio and left the board in January of 1972.

He left behind a 40 year legacy and a culture that endures today. His vision, although out in front of the technology and business return of his day at times, proved to be almost clairvoyant and was responsible for many of the achievements and the financial success of Collins Radio along its journey. . . Not to mention its influence on the future of Rockwell Collins.

Some say he lost the company. It is better described as guiding the company to a point of necessary transition.

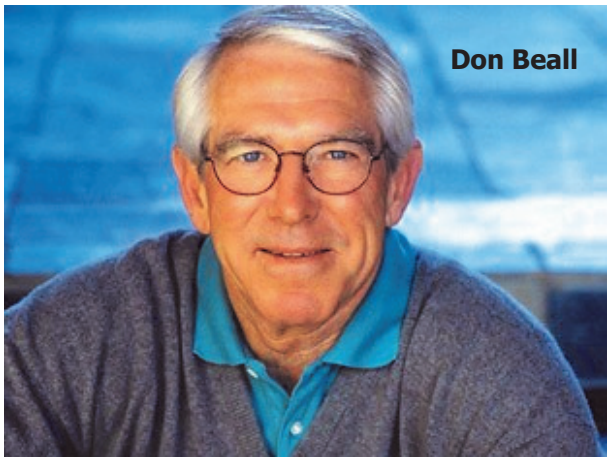
One can only marvel at the strength of the culture that he fostered where his work ethic and sense of quality and technology excellence were *de rigor*.

Arthur never lost his passion for working toward a better future technologically, just as he never lost the respect of his employees and peers.

He passed away in 1987 at the age of 77 having gone from Boy Wonder to seeing a Moon Landing where his radios were in use. He was, as they say . . . "A game changer".

trols were also implemented including "lights out when not needed" kind of things, reduced long distance calling, reduced travel, and even a temporary across the board salary cut.

All of the changes were not systemic. There were also structural/ organizational and cultural changes. He immediately attacked the very wide and deep functional organization issue by reducing the number of management layers from 9 to 5 and restructuring the company into a flatter market and P&L focused organization. In the process, there were an additional 2000 engineering and administrative positions eliminated. The company was reorganized into four new market oriented divisions (Avionics & Telecommunications – Headquartered in Cedar Rapids, Telecommunications and Switching Systems – Dallas based, Special Telecommunication Systems – Headquartered in Newport Beach, and International Operations – Dallas). Just as importantly, he made each of these organizations P&L centers with typically 3 or 4 P&L groups within each division. These changes clearly defined P&L responsibility for the first time - and moved visibility and financial control down into the organization.



Above all, Wilson emphasized that they needed to book, and service, available orders. Amazingly, the last several years ('67-'69 especially) had resulted in such emphasis on the "Future of Computers", that resources were siphoned off of other existing profitable businesses to the point of severely impacting the company's ability to ship orders.

To foster these cultural changes, Wilson brought in an outside training firm to develop the P&L management skills of a team that had previously been focused only on engineering, technical excellence and customer satisfaction.

The result was a structure with less span, shorter communications and control paths, and a real emphasis on both the customer and market penetration - while controlling the P&L. It all worked as planned. Cash flow before write downs turned positive almost immediately. However, including the write downs and restructuring costs, the financial result was, as expected, still negative in FY 1972 (a loss of $64M on sales of $250M). 1973 was a better story.

Collins Radio navigated FY 1973 with 20 senior officers (Bob Wilson as President & CEO, and 19 V.P.s). There were now three senior or executive V.Ps – one was a vestigial Senior V.P. of Engineering, Bob Cattoi. There were now nine (P&L) Marketing V.Ps (three were international markets) and seven were business/functional V.Ps (Corporate Operations -Washington, Corporate Development, Legal & Secretary, Industrial Relations, Finance, Treasurer, and Manufacturing). Wm. Roodhouse, Exec. V.P., served as Don Beall's #2 - playing a key role.

At this point in time, no fundamental changes had been made in the markets served by Collins Radio, or the basic businesses that they were in. That would change slowly over time. As part of the obvious shift to a market and P&L focused organization, and a more balanced approach to "going to market" (Technology, Quality, Customer and P&L), there was a purposeful increase in the role of Marketing and Planning. There was also an increased focus/expectation on international business levels and a better balance of commercial and government business. There was now a defined business strategy in place – as opposed to just getting business any place that you could get it.

The Jewel

In early FY 1974 (November of 1973), and having seen the positive results of FY 1973 (a profit of $13M on sales of $350.3M – up 40% over previous year), Rockwell moved to use its control over the Collins Board of Directors to merge Collins into Rockwell International. This was not unexpected given the "jewel" nature of Collins Radio and its obvious assets and potential. It did, however, have a negative side that Rockwell had not anticipated.

Bob Wilson had long coveted the CEO position that he had achieved at Collins Radio. When the merger occurred on November 2, 1973, he saw himself demoted from CEO of a growing and potentially successful company, to being a Division President and GM embedded within a much larger company. In March of 1974 he resigned and was offered a challenging CEO position of the then struggling Memorex Corporation.

Fate

Enter smiling fate again. Sitting on the Collins Radio Board of Directors, and as Executive V.P. reporting to Wilson, is Don Beall. Don has already been very instrumental in helping orchestrate the financial and management changes that have proven successful to date. He is immediately made the President and GM of the new Collins Division of Rockwell International.

Looking at the past performance of both men, and also at their future careers at Rockwell, Rockwell Collins and afterwards (Don's career at Rockwell and beyond, and Bob's at Memorex), it is safe to say that Bob Wilson was the surgeon that skillfully came in and did the face lift, and that Don Beall was the therapist that made sure that the future of the patient was taken care of. . . Fate!

Don Beal served as the head of the Collins Division for just 5 years. These were critical years that saw Collins grow stronger and ready for the future. In 1979, Don was tapped to become the President and CEO of the entire Rockwell International family. He did not replace himself and stayed very close to the daily management of the Collins Divisions.

During his tenure, slowly, the changing nature of several of the served markets of Collins dictated that business changes were in order. First, the computer effort was severely (and quickly) cut back. Some vestiges of that business folded back into the core Avionics and Telecommunications groups and much of Arthurs basic computer interface and data vision endured. In 1980, the Broadcast business was sold to Continental Electronics ending the Collins Division's participation in this mature and difficult market. Then, following the end of KWM-2A production in 1982 - and the final production of the HF/ KWM-380 and the HF 280 family in the mid-80s - Rockwell Collins quietly ended its participation in the Amateur Radio and low end commercial HF Markets.

The next (unexpected) served market change came in 1991 when Rockwell International sold its Microwave Group to Alcatel for $625M. This came as a shock to almost everyone concerned, but was omniscient given the changes that would later come in those markets driven by satellite and fiber data communications technologies.

The next and final big "streamlining" of the Collins Div. came spread across late 1998 & early 1999. Rockwell International first restructured some of its Semiconductor Products Division (SPD) fabs. Then, finally, the remaining CMOS and GaAs Semiconductor & Microcircuit operation was spun out as Conexant in 1999. The entire SPD operation had long been a problem child for Don Beall and the Rockwell P&L. This SPD operation was a combination of the previous Collins Radio Microcircuits and Semiconductor (Newport Beach) and the Rockwell Autonetics Div. Semiconductor group located in Anaheim. It was only in the later years following the mid-80s development of their Modem business, that SPD became profitable. The Modem business was a huge success (Rockwell dominated this market for many years)

Continued on p 48

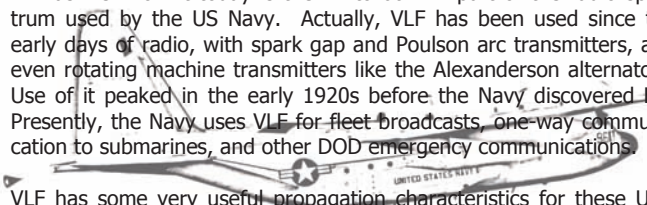
Fifty One Years of TACAMO
The Longest Running Program at Collins

by **Loney Duncan, W0GZV** - AC13-12852

During the 41 years that I was employed with Collins Radio and Rockwell International, I was impressed with the range of the radio spectrum that the Collins products and systems embraced: from VLF at the low end, to EHF, and even to light - with the light wave products in the Microwave Division. However, little known to many is the heavy involvement of Collins in the VLF, or Very Low Frequency part of the spectrum with the TACAMO program for 51 years, a program that still continues. To my knowledge, this is the longest running program in the history of the company. The following are some highlights of this program that may astonish you.

US NAVY VLF

VLF as we know it today is the 14 to 60 kHz part of the radio spectrum used by the US Navy. Actually, VLF has been used since the early days of radio, with spark gap and Poulson arc transmitters, and even rotating machine transmitters like the Alexanderson alternators. Use of it peaked in the early 1920s before the Navy discovered HF. Presently, the Navy uses VLF for fleet broadcasts, one-way communication to submarines, and other DOD emergency communications.



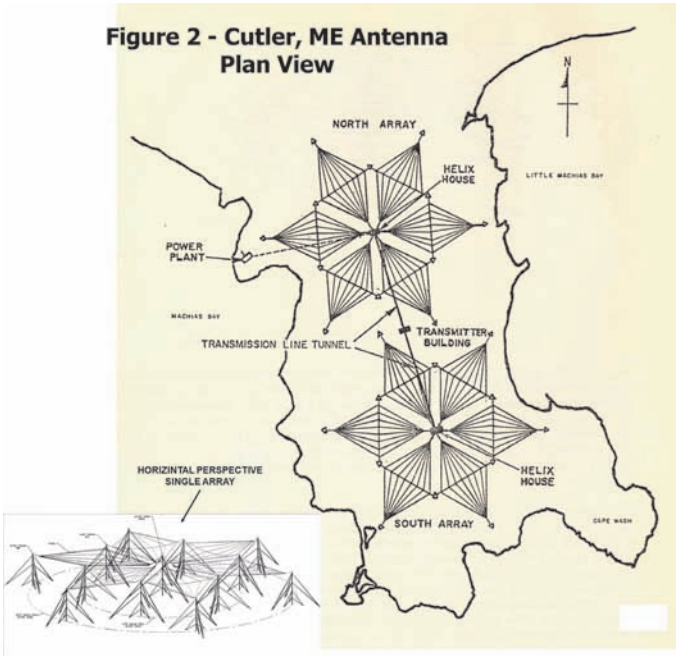
VLF has some very useful propagation characteristics for these USN broadcast applications. It provides very stable communications over long distances by both ground wave and earth/ionosphere D-layer wave guide propagation. It is least susceptible to all ionospheric disturbances, including auroral outages at the northern latitudes, and selective fading that is encountered so often with HF. It is the most stable frequency range during a nuclear event, the last out and the first to recover. And very importantly, it penetrates sea water sufficiently to allow broadcasts to submerged submarines with their trailing wire antennas.

However, VLF encounters high atmospheric 1/f noise compared to HF, and this, along with very geographically large broadcast areas involved, requires very high power shore stations. Figure 1 is a list of these stations during the cold war years of the 1960s and 70s when the TACAMO program was launched. Note that they are in the 1-2 megawatt power range, but have rather low antenna efficiencies of 10 -50 %. This is because of the very short electrical heights of their vertical antennas and the resulting very low antenna radiation resistances compared to RF resistances for ground and tuning losses. A 900 feet tower at 17 kHz, where the half wavelength is 28,928 feet, or 5.5 miles, is electrically very short. An equivalent 75 meter ham band vertical antenna would be only 4 feet high.

Call	Location	f (KHz)	PA Output	P ERP
NAA	Cutler, ME	17.8	2.0 MW	1.0 MW
NPG	Jim Creek, WA	18.6	1.2 MW	250 KW
NSS	Annapolis, MD	21.4	1.0 MW	100 KW
NBA	Summit, PCZ	24.0	1.0 MW	100 KW
NWC	NW Cape, Aus	22.3	2.0 MW	
NPM	Laulaulei, HI	26.1	1.0 MW	100 KW
NDT	Yosami, Japan	17.4	250 KW	

Figure 1 - List of Naval VLF Stations in the mid– 60s

The NAA Cutler, Maine station is one of the best of these and a good example to examine. Figure 2 is a plan view of NAA on 2000 acres, or three square miles of installation on this Maine peninsula. There are 26 towers of 800-980 feet height arranged in two 6-point star pattern arrays, each with a 3000 feet radius, one of the largest arrays in the world. These arrays heavily top-load the vertical antennas to reduce their capacitive reactance. There are over 2,000 **miles** of AGW-6 copper wire ground radials, and 200 sea anchors to minimize the ground losses for this station. There are two 1 MW transmitters, one for each of these star arrays, connected by one mile of 9-inch diameter coax line. This allows for one transmitter/star array pairing to be operating while the other array is being de-iced (up to 3 in. radius of ice) by an elaborate counter weight system and 60 Hz power during a Maine winter. Normally, both pairs are operated at the same time for a total power of 2 MW. The total on site 60 Hz power usage is 11 MW. Huge spherical variometers constructed of 4-inch diameter litz wire are used for tuning these electrically short antennas. This litz cable contains thousands of individually insulted wires that result in minimum RF loss at these frequencies. Figure 3 shows this type of variometer used in a similar station at Northwest Cape in Australia. Variable inductance is obtained by rotation of the inside coil and the mutual inductance coupling between the two coils.



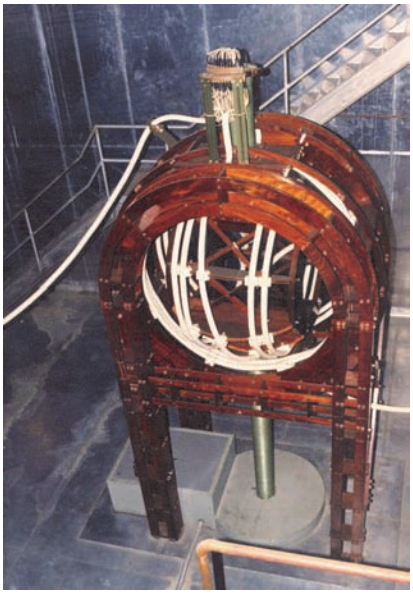


Figure 3 -

The Litz Wire Variometer used to cancel very high capacitive reactance of the shore station antenna arrays involved in VLF transmissions. Note the stairs in background of photo for scale.

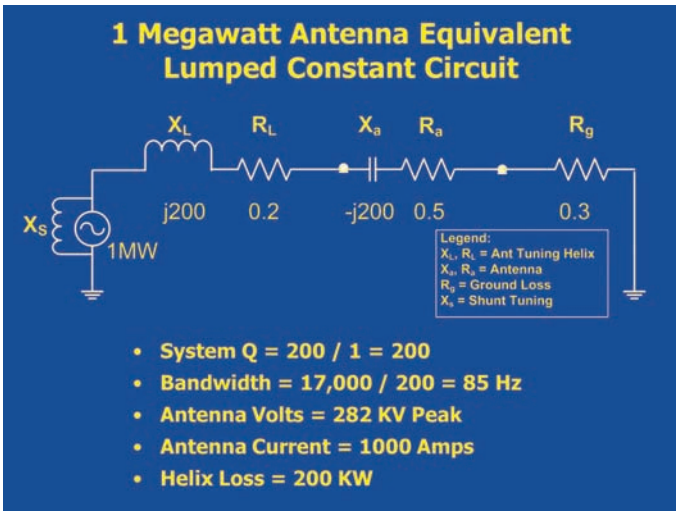


Figure 4– Typical 1 MW Antenna Equivalent Lumped Element Circuit

Figure 4 illustrates some of the antenna characteristics of these megawatt VLF stations. While the circuit values are not NAA exact, they are typical. Note that even with the elaborate, extensive top loading, the antenna capacitive reactance is still 200 ohms. And with over 2000 miles of ground radials and 200 sea anchors, the ground loss is still 0.3 ohms compared to a radiation resistance of 0.5 ohms. The huge, high-Q tuning helix has an RF resistance of about 0.5 ohms. All of this results in a radiation efficiency of about 50% and the resulting tremendous voltages and currents, and appreciable helix power losses, that are listed in figure 4.

Note the high system Q of 200 and the resulting low 3-db bandwidth of 85 Hz. This is a fundamental limitation on information rates that can be handled by these stations. As a result, they use the Collins Radio invented Minimum Shift Keying, or MSK, type of modulation to maximize the bit rates. Even so, 50 b/s, or 75 words per minute is the typical low keying rate for these high-Q VLF antennas.

The Navy began to have great concern about these essential shore stations. On July 20, 1960, the first ballistic missile was launched from a Polaris submarine, the USS George Washington. By 1962, there were eight of these subs containing 80 nuclear warheads, and the 3rd part of the DOD nuclear triad of bombers, land based missiles, and submarine missiles was formed. Cold war tensions were very high, and the Cuban missile crisis occurred in October of that year.

It had become very apparent to Rear Admiral Bernard Roeder, Director of Naval Communication, that none of the VLF shore stations listed in Figure 1 could possibly survive a nuclear attack, and yet VLF command and control broadcasts were crucial to these nuclear subs submerged for long periods of time. Moreover, it was difficult to have secure and jam resistant broadcasts to these subs with the low bandwidths of the existing shore stations. A paradyne shift for VLF emergency communications was badly needed.

In early 1962 Admiral Roeder assigned Lt. Jerry Tuttle to head a project that addressed this. As the story goes, Roeder handed Tuttle a scrap of paper with the words: **Take Charge and Move Out**. And the acronym **TACAMO** and a program name was born. Years later, (by then) Vice Admiral Tuttle verified this story in a public address. At any rate, Lt. Tuttle did immediately move out, and in May of 1962, the Navy rapidly awarded a contract to Collins Radio, Richardson, Texas for a prototype of a VLF system concept called TACAMO.

This basic concept was an airborne VLF relay platform, survivable and secure, that would receive emergency VLF, HF, and UHF transmissions from the USAF Airborne Command Post aircraft (EC-135s), process these, and relay command and control instructions by VLF to the submerged Polaris submarines. The proposed relay platform was a C-130 turbo prop cargo aircraft. The VLF operation would use 14-30 kHz at a transmit power to the antenna of 25 kW. The system would be operated at 800 b/s MSK keying rate, an enormous increase over shore station capability, and would have a "Communications Central" with four operator positions providing complete VLF, HF and UHF coverage using Collins radios.

The antenna would be a variable length, trailing wire type (one half wavelength at 14 kHz) and therefore be 35,000 feet, or 6.7 miles, long. The aircraft would have to execute an orbiting maneuver to cause the normally straight-in-flight trailing wire to become substantially vertical, in order to have sufficient vertical polarization to penetrate the sea water. This verticality was an absolute requirement, and the success of the TACAMO concept hung on this unique concept.

Collins (Richardson, TX) had experience during this period with straight-in-flight VLF trailing wire antennas for the USAF Airborne Command Post ARC-96 VLF system on EC-135s. These were for the 30-60 kHz frequency range that the Air Force used. I'm sure that this influenced the Navy to award the TACAMO prototype system to Collins for quick delivery, but an orbiting (14 kHz) longer length antenna was far more difficult to design than the ARC-96 Air Force antenna. Nevertheless, Collins completed the prototype system only five months after receipt of order, completed testing it on a Marine Corps F-130, and delivered it to the Navy by the end of December 1962. This certainly exemplified the concept of Take Charge and Move Out! This first prototype was called TACAMO I.

TACAMO I-III

The prototype transmitter was a 25 kW push-pull, Class AB linear type, using two Eimac 4CX15000 ceramic tetrode air cooled tubes. Class AB linearity was required to reduce the RF harmonics and minimize the output network complexity. The network only required two variometers and a fixed capacitor to tune the antenna.

The trailing wire antenna consisted of a hydraulic driven reel with a special mechanism for **perfectly** spooling the 35,000 feet of 0.2 inch diameter stranded steel cable that was double wrapped with copper ribbon for better RF conductivity. The end of the trailing wire was fastened to an 80 pound conical drogue for aerodynamic stability. The antenna unit, or "Group", was constructed in pallet form for easy removal from a cargo C-130. Figure 5 below shows this 10,000 lb. pallet antenna, which extended or retracted the 35,000 feet of wire in just 45 minutes. Also, both the transmitter and the Communication Central were in pallet form - each with their own pallet.

This end fed, half wave antenna had a low Q and high radiation resistance compared to the electrically short, shore station antennas. This allowed the much increased 800 b/s keying rate, and also resulted in relatively low ground (sea water), trailing wire, and matching network losses. The antenna reeling machine was insulated from the aircraft, and had to operate at a peak antenna voltage of 25 kV when fed with the 25 kW transmitter.

Figure 5 - EC-130 Antenna Pallet

The Navy flew the TACAMO I prototype system for two years, learning how to orbit the aircraft, and in general proving out the VLF relay concept. There were valuable lessons learned. In 1964 the Navy contracted with Collins to build and install four systems based on the pallet prototype, but with certain improvements. These four aircraft were considered to be Operational Evaluation Production units, and were flown for four years as VLF operational relays. Fig. 6 displays the pallet concept in the C-130Gs designated TACAMO II units.

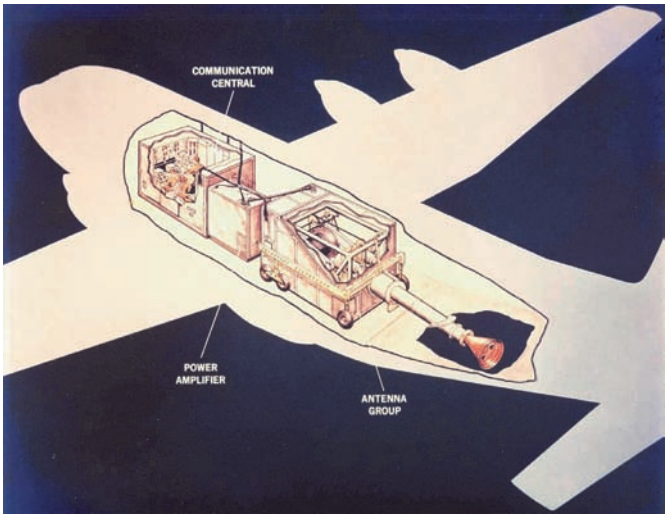


Figure 6 - C-130G TAC II Pallet Load Configuration

By 1968, the Navy concluded that the pallet concept should be replaced with a totally integrated aircraft approach, and Collins was awarded a contract to design, build and install twelve TACAMO III systems on EC-130G/Q aircraft. The airborne Communication Central was expanded to include more HF and UHF radios, and increased transmit and receive modes. Dual HF antennas were installed for diversity reception, and a processor controlled in-flight monitoring system was installed. And….. for the first time the crew comfort facilities were expanded.

Improvements were made on the trailing wire antenna to increase its reliability. The transmitter was considerably improved by applying 30 dB of feedback to reduce harmonics to the FCC required -80 dB level. This also reduced transmitter noise to the -120 dB level for better VLF reception 5 kHz from the transmitter signal. The variometers were improved, and auto tuning was installed.

Also, at the insistence of Arthur Collins, processor control and monitoring was installed in the transmitter using the Collins 8311 minicomputer and A/D converters and Mux/De-mux circuits. This was certainly a first for the Navy.

The Navy created two new squadrons to receive the twelve TACAMO III aircraft. VQ4 was formed at Patuxent River, MD for the Atlantic Ocean patrol, and VQ3 at Agana, Guam for the Pacific. Since there were more Polaris subs in the Atlantic, 8 of the 12 new systems were first sent to Patuxent River. This later changed to an equal number of aircraft in each squadron.

Figure 7 illustrates the layout of the TACAMO III installation with the 4-position Communications Central, the racked up radio equipment, and the high power transmitter and trailing wire antenna. The aircraft had several HF wire antennas. Also note the prostrate antenna reel operator peering through a port hole at the extending trailing wire antenna. In the next generation of TACAMO that drastically changed.

My personal career with Collins intersected the TACAMO program with the start of TACAMO III. I was the Division Director of Collins Engineering Division K, with HF engineers in Cedar Rapids, and high power transmitter engineers in Richardson. We had just finished the design of the second generation of a 250 kW shortwave broadcast

Figure 7 - TAC III VLF Load Configuration

transmitter, the 821A-2, and shortly after - in 1968 - we launched into the design of TACAMO III. I was a part of the TACAMO program through the fourth generation system.

TACAMO IV

The Navy attempted to mirror the USAF Airborne Command Post operation of having some aircraft flying 24/7. With the continuing increase in the number of Polaris subs, and greater areas to patrol, it became more difficult to adequately control them with the 25 kW power level of the TAC III systems. The Navy concluded that it needed TACAMO systems with substantially more power. This led to the TACAMO IV program and enormous technical challenges.

The USN requested TACAMO IV bids for a 200 kW VLF transmitter for 17-30 kHz instead of the original 14-30 kHz. Navy would install four 90 KVA, 400 Hz, 3-phase alternators on the C-130s to accommodate this, but it was evident to all that the transmitter would have to be a very high efficiency type, certainly not like the linear, relatively low efficiency, TACAMO I-III transmitters.

Westinghouse had supplied the Air Force Airborne Command Post aircraft with 20 kW solid state transmitters, and bid this approach at the 200 kW level. Not surprisingly, they won the contract. Collins was very dubious about power transistors being practical (*at that time*) for this TACAMO application. We told the Navy, "Someday, but not now". This proved to be a correct position when Westinghouse was not able to deliver a reliable transmitter. The Navy was then open to a Collins alternate approach employing vacuum tubes in the PA.

Although Collins had never produced a transmitter with better than class-c plate efficiency of about 75%, it quickly designed a 25 kW demonstration transmitter (affectionately named *Old Kludge*) using a unique Tyler circuit to provide a plate efficiency of 90% at VLF. Briefly, this was accomplished with a 180 degree rectangular waveform driving the PA tubes, and then a second harmonic series trap in the plate circuit. This arrangement would flatten the top of the plate sine wave voltage during the tube conduction period, and reduce plate losses for a much better efficiency.

The demonstration worked superbly, and the Navy was impressed. This led to Collins winning the 1972 TACAMO IVB competitive contract for not only the 200 kW transmitter, but also for a new trailing wire antenna system. This new antenna design was definitely required because of voltage limitations of the existing antennas and the higher applied voltages at the increased output power.

Transmitter: The Collins 200 kW transmitter was designed around two vapor cooled Eimac 4CV50,000 ceramic power tetrodes. We had considerable experience with this type of tube because of the 821A-2, 250 kW HF transmitter with its two 4CV100,000 tubes. The 4CV50,000s were powered by 10,750 Vdc on the plates, from the transmitter's 400 Hz, 3-phase power supplies. The arrangement of these supplies is illustrated in Figure 8, along with the waveform that was flattened in order to produce higher efficiency.

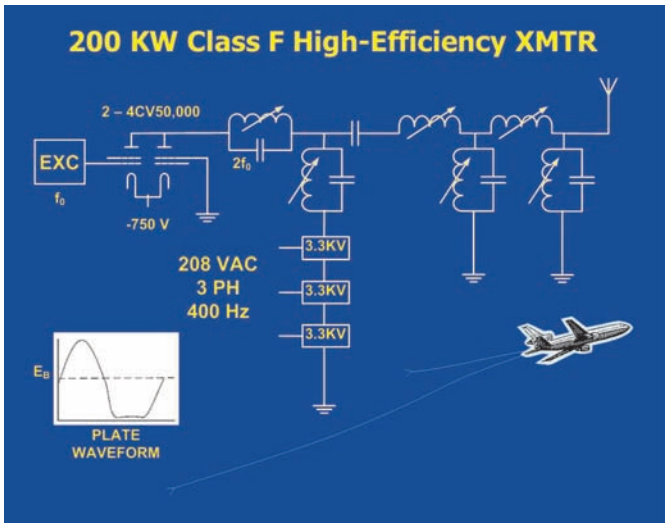


Figure 8 - 200 KW Achieved with Supply Stacking

Obtaining high plate efficiency was one thing, but simultaneously being able to reduce transmitter harmonics to the FCC's required minus 80dB, from a highly non-linear transmitter, was quite another. The only practical way was with a very complex output network, which would also tune the antenna. We used a 3-node, synchronously tuned, band-pass network consisting of five large variometers and three extremely low loss ceramic fixed capacitors. These were in addition to the second harmonic trap which also contained a variometer and ceramic capacitor. The efficient variometers were constructed of litz wire and were in the low millihenry range. The low loss ceramic capacitors were 8000 pf each with astonishingly low losses at VLF.

Figure 8 also illustrates the output network approach. From the left, the second harmonic trap variometer and the next two shunt units were prepositioned with frequency information. The series variometer between the two shunt units was servo controlled by a 90 degree phasing discriminator for node synchronous tuning, and the series and shunt output variometers by phasing and loading discriminators for impedance matching the antenna. All of the variometers were totally auto-tuned for any 17-30 kHz frequency in a maximum of 30 seconds, and continuously matched the antenna during flight, including the orbit maneuver. Collins was more skilled than any other company in auto-tuning transmitters and impedance matching antennas.

The 200 kW airborne transmitter is shown in Figure 9. With the front covers off in Figure 10, the power tubes are shown in the upper center connected to a vapor cooling heat exchanger on top, which in turn was connected to a heat exchanger in the aircraft slipstream. Large power supply components are in the lower right compartments, and the computer components (adapted from TAC III) are shown installed below the tubes. Remember—This is an airborne aircraft transmitter!

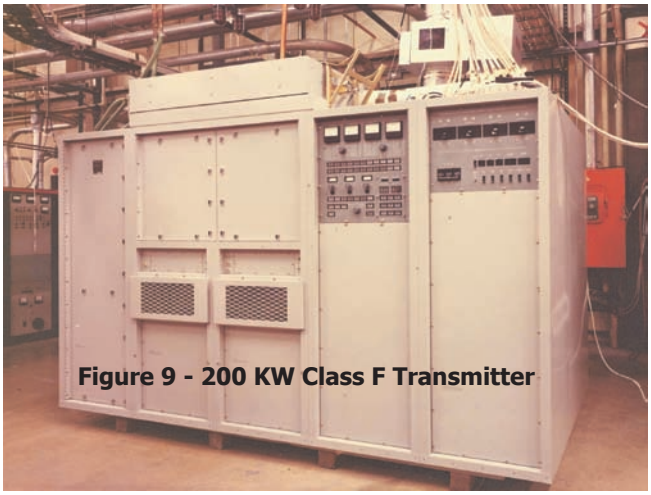


Figure 9 - 200 KW Class F Transmitter

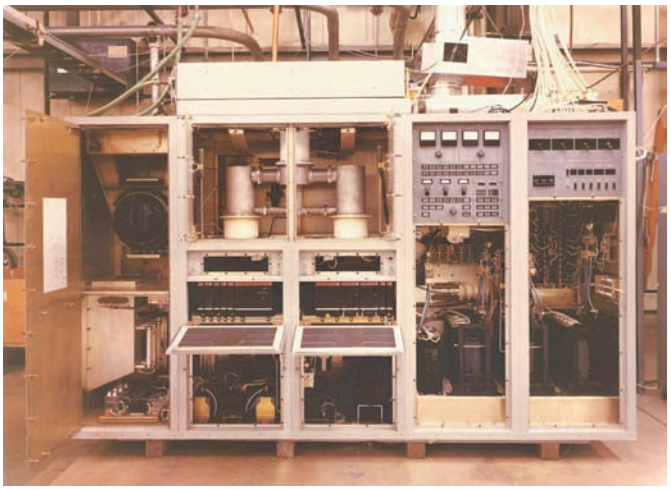


Figure 10 - 200 KW Transmitter PA Tubes - (Above)

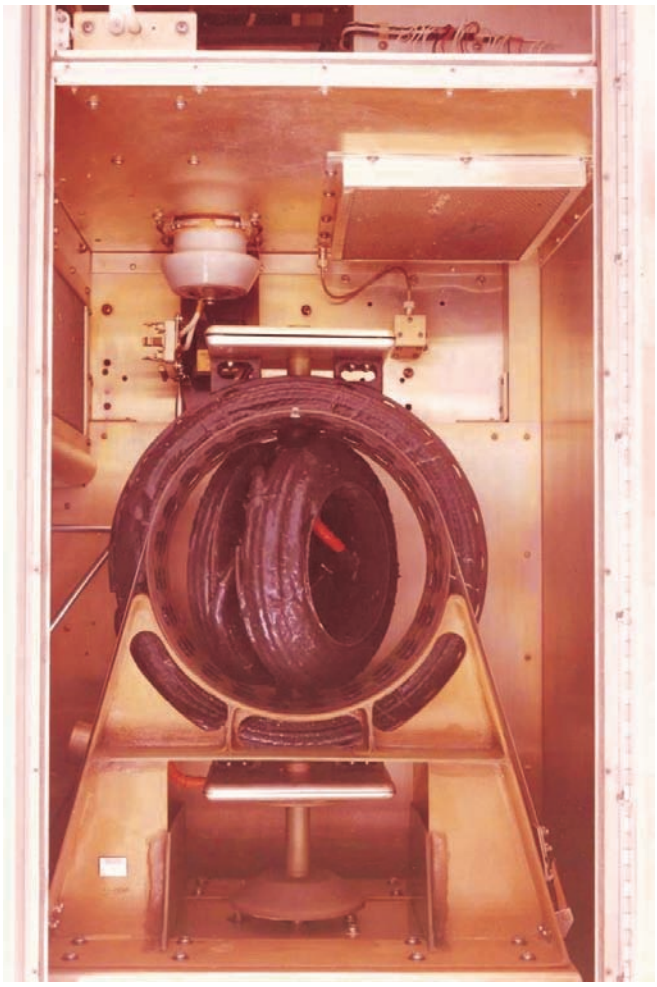


Figure 11– One of six large Litz wire silastic impregnated variometers

All of the band pass network components were in several compartments on the back side of the transmitter. Figure 11 shows one of the six large, litz wire spherical variometers, and one of the ceramic capacitors above it. Both carried over 20 KV peak voltages and 70 Amps of RF current. The variometers had to be air cooled.

All of the variometer litz wire windings were vacuum impregnated with a silastic material. This removed all possible air bubbles enabling the units to handle these high RF voltages. This process was very costly to develop, but exceptionally successful over several decades in preventing inter-winding RF voltage arcs on these variometers. It was a major technical breakthrough for the transmitter project.

Trailing Wire Antennas: The Navy raised the lower VLF airborne operating frequency limit from 14 kHz to 17 kHz in order to reduce the trailing wire length, but at the same time required the extend time to be reduced from 45 to **6** minutes. Also, the wire diameter was reduced from 0.2 to 0.16 inches. Collins insisted that the only way this high extend speed could be accomplished without breaking the wire, would be with a totally automatic, servo controlled system, with the reel operators essentially out of the loop. The Navy agreed.

Additionally, Collins maintained that, with 200 kW, the 25 KV max antenna voltage could only be met by employing two trailing wires instead of the single one of TAC I-III. In principle, this was like a substantially off-center fed dipole, where the ratio of short and long wire lengths could be adjusted for about a 900 ohm source resistance - which was much lower than that of an end-fed single wire, and thus reduced the max antenna voltage. It was proposed that the long wire be grounded to the aircraft, and the short wire be fed by the transmitter. All of this was a radical and costly departure from TAC I-III. The Navy again agreed, and this approach proved to be very sound.

The long wire antenna was wound on a huge reel with a Lebus fleet angle compensator [1)] as a wire guide mechanism for perfectly spooling 42 layers of wire for a 28,000 foot length. The reel and Lebus are shown in Figure 12 below. The reel used a 60 HP hydraulic motor to both retract, and slowly extend, the antenna.

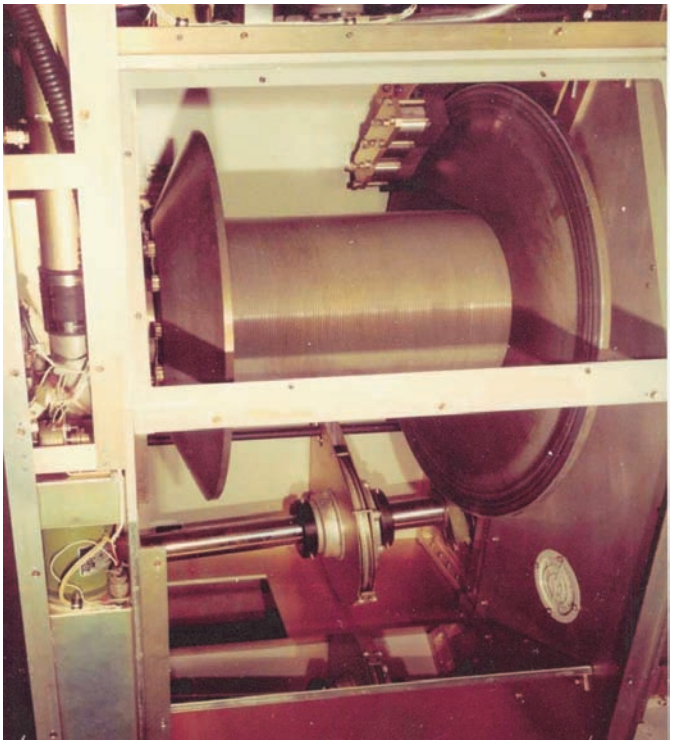


Figure 12 - LEBUS high speed wire guide

1) The LEBUS mechanism is a complex geared and servo driven guide for the incoming wire that assures that wire on reel placement is exact.

For the rapid 6-minute extend cycle, a large servo controlled disc brake was used. Because of a peak dissipation of 220 kW at the very high extension rate of 6,000 feet/minute, this brake was vapor cooled by injecting water into the hollow disc, and venting the resulting steam overboard. There were 15 gallons of water which allowed such cooling for two complete full extends. While temperature inside the disc was 220 degrees F, temperature on the outside surface which was in contact with the servo controlled pad was 565 degrees F, requiring the pad to be constructed of a very durable high temperature material. Figure 13 shows the disc brake and its pad in a test fixture.

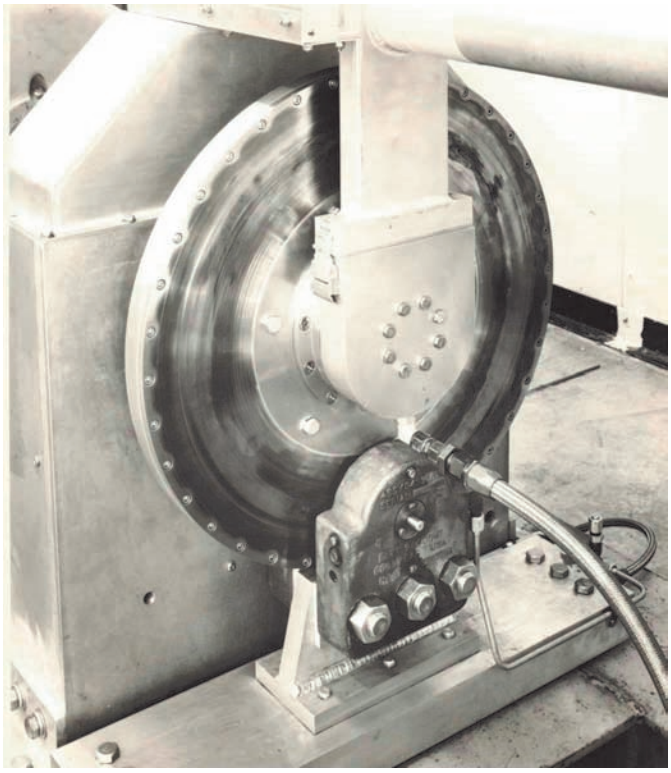


Figure 13– High Speed Reel Brake Disc and Pad Assembly under test

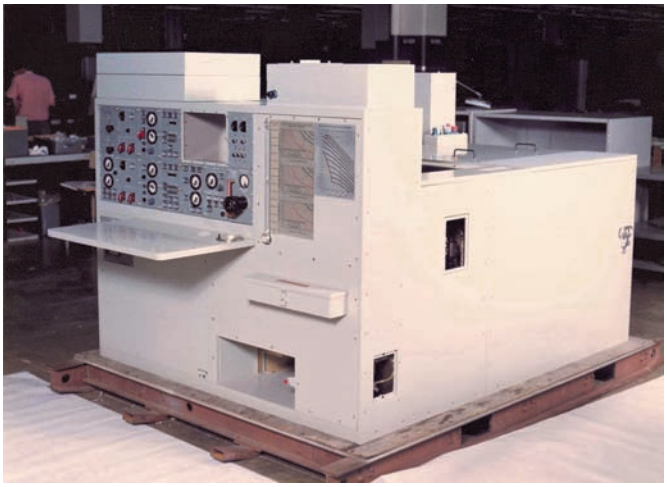


Figure 14 - Complete Antenna Group for TACAMO III on a pallet ready to install

The operation of the complete 17 kHz long wire antenna unit as shown in figure 14, was exceptional. Typically, a wire length was dialed into the unit, the *Extend* command given, and the hands-off total extension cycle was accomplished in less than 6 minutes.

Linear positioning accuracy was typically 10 to 15 feet….And this was done without endangering the wire. For anyone who has tried an aggressive cast with an old style open fishing reel, only to wind up with a huge tangle of line, the accomplishment of getting 28,000 feet of wire spooled out from a drum in 6 minutes can only be admired.

Critical to the successful development and testing of these long wire antennas was a very complex, high-speed test reeling machine named "Mother Nature". Shown in Figure 15, this system used a servo controlled 300 HP DC motor to run a take-up reel for the antenna. With its processor smarts, the system at any moment in the extend cycle echoed the aircraft speed, altitude, and resulting aerodynamic drag on the wire. This allowed accurate duplication & testing to the airborne conditions we experienced. It was indispensable to the program.

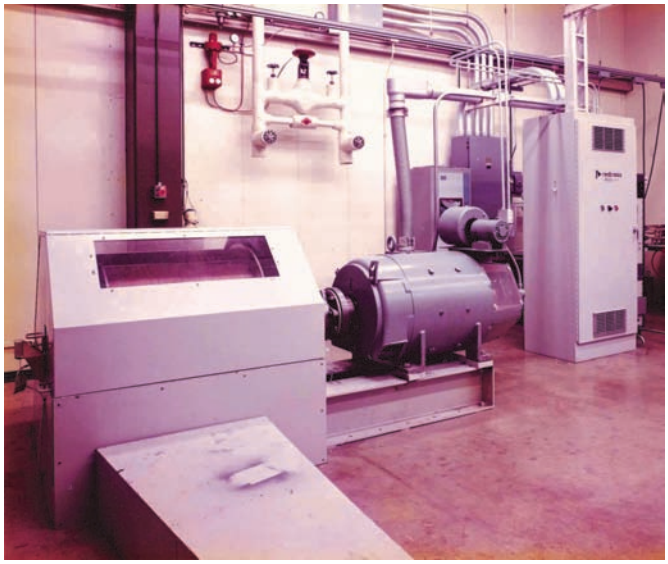


Figure 15 - "Mother Nature" - The test fixture for wire deployment from the Reel & LEBUS Assembly

The 0.16 inch diameter wire was constructed of 19 strands of steel rocket wire that was double wrapped with copper ribbon. It had a breaking strength of 2550 pounds, and under normal conditions, no more than a max 1900 pounds was applied. The short wire antenna wire was of the same construction but with only a single layer of aluminum ribbon wrap. With a total antenna system source impedance of about 900 ohms resistance, the antenna radiation efficiency was close to 85%. This was significantly higher than that of the shore station antennas of Figure 1.

The Orbit Maneuver: As previously discussed, the normally straight flying long wire had to be vertically oriented to effect sufficient vertical polarization to penetrate the sea water. Briefly, this was accomplished by a somewhat complex orbital (or turning) maneuver.

Normally, the C-130 aircraft flew at 220 knots for a *fast extend*, and 170 knots for a *retract*. But for the orbit, it would slow to about 130 knots, fly in a large circle, and reduce the circle radius to about 1/3 the long wire length, which at 17 kHz was about 8,000 feet. With the aircraft flying at a bank angle of about 22 degrees, and this 8,000 feet radius, the normally flying long wire would stall into a partial spiral. This would increase the normal 800 pounds of wire tension to about 1200, and increase antenna verticality to about 70%. At the same time, the aircraft crew would pull a fatiguing incremental 0.5 Gs.

The bottom line out of all of this was that, from the product of the 85% radiation efficiency and the 70% verticality, the effective vertical radiation efficiency was about 60%. Thus, for 200 kW into the antenna, about 120 kW was vertically radiated for submarine broadcasts. Referring back to Figure 1 on page 12, while the 120 kW does not come close to the radiated power of Cutler, Maine, it is only 3 dB down from Jim Creek, WA, and well on par with some of the other more inefficient shore stations.

TAC IVB System Deliveries: Starting in 1974, Collins installed 16 of the newly developed and manufactured TAC IVB systems into Navy EC-130G/Q aircraft. These aircraft were brought to the Collins aircraft installation facility at Addison, TX in the Dallas metroplex. The transmitters and antennas were thoroughly tested and burned in before installation. Figure 16 illustrates the TAC IVB aircraft configuration. To the rear of the 4-position Communication Central, was the racked up VLF, HF and UHF equipment. Aft of the comm rack was the 200 kW transmitter, and then the long wire and short wire antennas. Note that the short wire exits the aircraft level with the horizontal stabilizer, while the long wire exits much lower. Conspicuously absent with these auto-controlled antennas, is the prostrate reel operator shown in Figure 7 for the TAC III antenna.

Figure 16 - Complete TACAMO IVB Installation

The EC-130G/Q is shown in flight (below) in Figure 17 - - one of my favorite photos. Note the two 80 pound conical drogues just exiting the aircraft and the slow speed pitched up attitude. These 16 aircraft were delivered to Guam and Patuxent River in equal numbers, and performed the TACAMO mission faithfully and successfully for many years. There's no doubt that the increase in transmitter power and the additional engineering effort was justified.

EC-130G/Q Deploying its drogues prior to orbit

During this same period, four modified TAC IVB systems were delivered to Boeing for installation on four E4B (Boeing 747) aircraft for USAF Advanced Airborne Command Post installations.

These advanced Air Force systems operated over the 17 to 60 kHz frequency range, and at a 1600 b/s keying speed. These four aircraft systems are still in use by the Air Force today. A testimony to their effectiveness.

I should say here; this period of the TACAMO IVB development and delivery, with its enormous technical challenges, coincided with the very worst period of Collins history. We had consistently reduced staff for many calendar quarters. Arthur had lost the company and Rockwell completely taken over. Moral was low, and to make matters worse, newly formed Electro Space, Inc. (nearby) was hiring away many of our key engineers. Rockwell cost controls, and the new culture, were paramount. Notwithstanding all of this, our Division's engineers did a superb job of designing and delivering this system.

Post EC-130G/Q: In order to reduce aircraft deployment time, the Navy decided to use the Boeing E6A (707) for TACAMO IVB. After many years of successful service on the EC-130G/Q turbo props, the 16 TAC IVB systems were transferred to E6A jets, starting in 1985. Of course these aircraft had greater speed and range than the EC-130s, but were much more difficult to orbit, requiring a 40 degree bank angle at 17 kHz, and subjected the aircraft crew to a considerably higher 0.9 G level during orbit. This resulted in the development of the Orbit Enhancement System, where the wire tension sensors were coupled to the autopilot to aid the pilot during this more difficult orbit. TAC IVB on E6As operated successfully into the mid to late 1990s as they were being replaced by **HPTS.**

HPTS and Solid State

The Navy never lost its interest in a solid state TACAMO transmitter. In 1985 the Navy asked for 35 kW demonstration transmitters from both Westinghouse and Rockwell Collins, with the intent of again completing 200 kW units. From what we could determine, Westinghouse again used silicon bipolar transistor technology. Collins, in contrast, employed power MOSFETs. In the years since the original TAC IV contract for a solid state transmitter, the MOSFETs had substantially increased in power level, driven largely by both the power supply, and strangely enough, the plywood industries. The plywood industry used RF heating to dry the laminate glue and employed MOSFET Power Amplifiers. We saw many advantages of the MOSFET over the bipolar transistor.

Collins developed a 7.5 kVA MOSFET module as a building block for higher power levels. Using five of these in series, Collins built a rugged, successful demonstration unit. Westinghouse was not successful again, which surprised us. Our original position in the early 1970s "that the day would come when solid state would be feasible for a 200 kW transmitter, but not now", was vindicated. Our success led to the 1987 High Power Transmit Set (HPTS) contract for a 200 kW unit, and strangely, a new antenna system, which will be explained shortly.

HPTS Transmitter: Figure 18 illustrates the strategy for the transmitter. Thirty-two of the 7.5 kVA plug-in modules, each containing 32 power MOSFETs, were connected in series for 200 kW. A 208 V, 3-phase, 400 Hz supply powered every four module with 270 Volts and 20 Amps for each module.

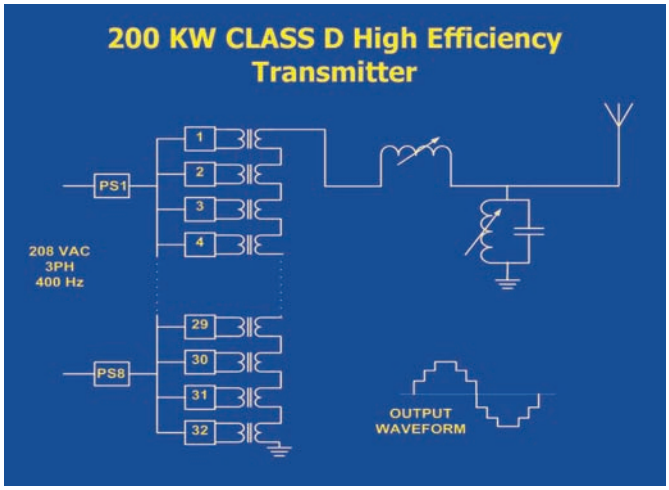


Figure 18 - 200 KW Modular MOSFET High efficiency Transmitter Design Concept

Very skillful waveform control greatly reduced transmitter harmonics to the point that the 6 variometers and 4 capacitors of TAC IVB were reduced to only 2 variometers and 1 capacitor, the number we previously had for the TAC I-III linear transmitters. This was a tremendous advantage in weight, space and cost, and a key attribute of "solid state". We simply could not do this at 200 kW with vacuum tubes. Figure 19 is a front view of the transmitter showing the 32 plug-in RF modules and their 8 power supplies. It is noteworthy that Rockwell Collins later developed 30 and 60 kVA modules for constructing up to one megawatt VLF shore stations using the HPTS MOSFET approach. This design has been very robust and reliable.

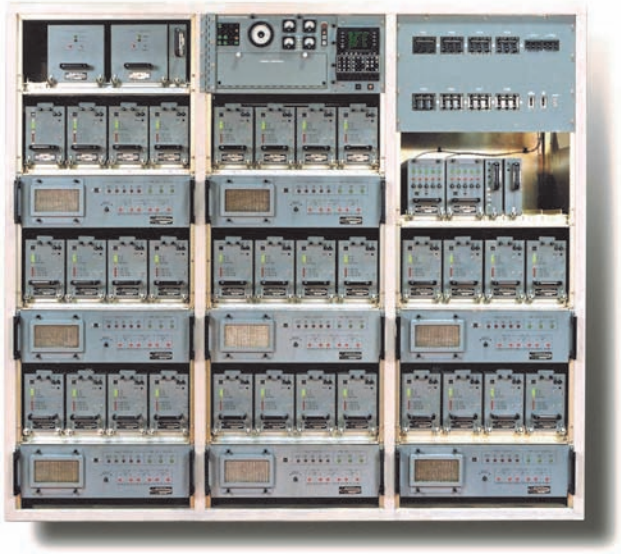


Figure 19 - 200 KW Modular MOSFET Modular Construction - Front View

HPTS Trailing Wire Antennas: There were unfortunate, new Navy requirements that resulted in a new dual trailing wire system for HPTS. Although the TAC IVB antenna system had worked well when transferred to the Boeing E6A, the Navy later came out with a max brake temperature spec of 400 degrees F for the similar E6B. As I mentioned, the disc brake outside surface temperature was 565 degrees F. In addition, Navy agreed with the USAF to a common design which would accommodate the upgrade of the Airborne Command Post EC-135s, resulting in undesirable dimensions on the reels because of that aircraft's space limitations. Later, due to lack of funds, but after the new design was completed, the Air Force would cancel their requirement for the EC-135s.

As a result, Collins came up with a new design for HPTS that fast extended with an 80 HP hydraulic motor which largely dissipated the extend energy into existing heat exchangers in the aircraft's fuel tanks. The "extend rate" performance was essentially the same - 6 minutes max of TAC IVB - but at the high cost of a brand new design that, although an excellent one, would have been unnecessary except for the 400 deg. F spec and the futile Air Force EC-135 requirement.

HPTS Delivery: Starting in 1991, sixteen of the HPTS Systems were installed in E6B aircraft which were similar to the E6A, but with a different electronics configuration. On the next page, Figure 20 shows the E6B in flight with the HPTS dual trailing wires just extending. HPTS and the E6B configuration can be considered a 5th generation TACAMO.

TACAMO Today

One might expect that, with the end of the cold war, TACAMO would eventually become a relic of that era. Interestingly, it did not. Both TACAMO IVB and HPTS flew for many years in the conventional mode of a VLF relay - receiving emergency messages from the USAF Airborne Command Post EC-135s as originally intended. During that time, numerous Defense Nuclear Agency reports throughout the DOD confirmed TACAMO's effectiveness.

Figure 20 - TAC IVB HPTS E6B in Flight with Drogues Coming Out
(Rear Drogue Inset)

Then, on October 1, 1998, the unusual happened. The Airborne Command Post mission was completely transferred from Air Force to Navy TACAMO. A Navy Air Wing was formed at Tinker Air Force base, Oklahoma City, and the whole consolidated mission was centered there. Over 1100 military and civilian personnel at Tinker supported this new mission. And the same two Navy TACAMO squadrons, VQ3 and VQ4, were stationed at Tinker.

The E4B aircraft was reconfigured to accommodate this new DOD Triad mission with a general officer and battle staff aboard. Air crews consisted of 2 pilots, 3 flight officers, and 10 sailors. Communication electronics on this aircraft ranged from VLF to EHF. And …… the Navy stated that there was more communication equipment aboard this E6B than on an aircraft carrier. Figure 21 illustrates the general configuration of this aircraft.

Figure 21 - NAVY Command Triad E4B TACAMO Aircraft Configuration

So we see today that TACAMO no longer is just a VLF communications relay to submarines, but is the total emergency Command and Control Comm for the DOD Nuclear Triad - a vital mission indeed and one that is both survivable and enduring. The TACAMO saga has played out for 51 years, and Rockwell Collins personnel continue to support this program, a worthy legacy, and one of which they can be justly proud. This is not only the longest running program at Rockwell Collins or Collins Radio but may also be the longest running program in the US Armed Forces.

de Loney Duncan, W0GZV

Editor's Comment: We are fortunate indeed to have the perspective and writing contribution here from one of the key executives of Collins Radio during the transition time to Rockwell stewardship. His article provides us with a unique window into the TACAMO program and the operation of Collins during this period….and, did you notice the units—I mean... "miles of antenna - 70 Amps of RF current….. 10,000 pound "airborne" transmitters . . .and spooling out 6 miles of wire in 6 minutes. Now...THAT is engineering.

CCA Business & Activities

Looking Back on 2013

2013 will go down in our history as a "Very Good Year". The membership is at an all-time high with more than 100 new members since the beginning of the year. Retention is excellent, particularly given the economy, and I am really pleased to see that many of our new members are young hams intrigued by the vintage nature of the equipment and the "Collins Aura" of quality – People and Equipment.

From an activity standpoint, it has been a super year. It is hard to avoid superlatives. The number of annual events has grown from two (Dayton & Dallas) to five, and the intention is to hold at that number for now. Since ARRL Midwest was a one time meeting (for them and for us), we will be replacing that event with a new one. Folks in the East and the South have long been clamoring for their own meeting.

It is our pleasure to announce that the CCA will be holding their first East Coast/South Event on the weekend of the 7th of February at the Orlando HamCation. We have already started the arrangements and a nicer group of folks I have not met. You all will enjoy this one. We will have the standard fair – A nice booth and hospitality area at the show arena (Building 2) and then a dinner and program at a venue to be announced. By the time this hits your mailbox, the new 2014 Events Calendar will be up on the website and the details will be filled in.

Bottom line – We saw you at Dayton, Dallas, Rochester, Pacificon and the Lebanon, MO at ARRL. Great Memories! I only missed one and that was because of a complete debacle on United Airlines. Thank you Jim Green for picking up the ball.

The website has again grown this year by leaps and bounds, and the big deal is that our database for members is now automated and included in the website data and you are able to use the Member's Only area of the website. Once the smoke clears on the *Signal Magazine* Anniversary issues, we will again be able to focus more attention on making the website even better. The 2014 changes will include more people information (biographies and the like) and also we will continue our efforts to increase the detailed information on the various models of equipment that we love. My continued thanks to our IT guru, Scott Kerr, KE1RR, for his support of the site and other various activities.

So, as we go into 2014, here is what we see ahead. With the membership at an all-time high, and the association very financially sound, you can look forward to a busy and exciting year. It is, after all, the 20th anniversary of the founding of the Collins Collectors Association. That will be our central theme for the year and the events will be of a celebratory nature with great entertainment and speakers. I always liked Sapphire – Good color….

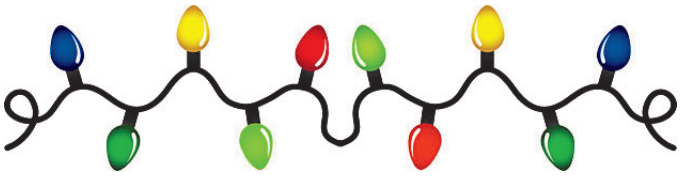
The *Signal Magazine* will also be carrying some "past" oriented stories along with the regular fair. Don't be shy if you think you have a story to tell, or a technical or historical perspective to share. We need good material.

The nets will continue as they have been – run by quality net managers and fun times for all. We will continue to try and have more fun "Challenges" to get that older gear back on the air and of course we will be trying to coordinate good 40 meter AM QSO activity with FIFI.

Without a doubt, this could all not have happened without a lot of help from a lot of people. First, to the many people who wrote and helped with the Anniversary issues of the *Signal Magazine* – My Eternal Thanks. It was a big effort and never could have happened without you. To the people at Rockwell Collins who helped with research and provided material, again, thank you so much. This includes not only folks still working at Rockwell Collins, but also the many retirees who spent hours on the phone or visiting in person and the year went by. Sadly, we lost several folks during the year, and they are remembered here, and always.

Scan to see more about the CCA

Special thanks go to the Rockwell Collins Investment Relations Group, and to the Brand Management Group for the wonderful help with financial data and reports, and the Rockwell Collins current advertisements. Also special thanks to the Museum folks, and specifically Lawrence Robinson, for his tolerance of my constant questions.



To all of you, our best **Holiday Greetings** and a wish for the health and happiness of you and your families. Happy New Year to all of you! …. from your CCA Management and *Signal Magazine* staff

2014 – A Look Ahead

2014 is going to be a very special year. We will be honoring our founders and our President Emeritus, Bill Wheeler, K0DEW, as well as just plain having a great big yearlong birthday party at our 5 coming events. Like I said, please see the website and our Events Calendar for the details. We are counting on seeing a lot of you newcomers come to at least one of the events. If you can not make the "live" events, then for sure come and see us on the nets.

The *Signal Magazine* will be back to its more normal format with a mix of Association Business, historical material and technical articles as well as an occasional insert of two during the year. Don't know about you, but I missed the little inserts. Don't worry, the quality will stay right up there and we hope you will enjoy!

I should say here that, because of rising postage costs and the size of the magazine, we have decided to go to "Permit Postage" which can impact the delivery time of the magazine. Our first run with this permit mailing was the Q3 issue and we did see delivery spread out a bit. Please understand and be patient. We are trying not to raise the dues.

Also, as you know, this quarter we are starting our every two year election process that assures that new blood and fresh perspectives come into the group. The details will be covered separately in the *Elections – 2014* section just ahead, but looking at the coming year, we will be seeing new faces and hearing from new, or maybe old, friends and we are looking forward to that. It is sad to see members of a good team move aside, but they all (Jim Stitzinger, WA3CEX and Karl Bowman, W4CHX) have assured me that they will be close at hand supporting the group and we thank them for their past contributions and for their help during the transition period and in the future. Word has it that we will see them again in that future - and that is a very good thing. Bottom line, I am looking forward to working with the newly reshaped team.

The membership growth rate shows no signs of abating at this point, so I think I can safely say that 2014 is going to be another Very Good Year.

We all are looking forward to 2014 and beyond.

CCA Board Elections - 2013/2014 - As announced in the Q3 issue of the *Signal* and posted on the CCA reflector, nominations for the two open Board of Directors positions were open during the months of October and November. During that period, there were two nominations posted. Paul Kluwe, W8ZO was nominated for Karl Bowman's board position and Dennis Kidder, W6DQ, was named as the candidate for the slot held currently by Jim Stitzinger who is our Secretary. Due to, again, having only one nominee for each position, we will not be mailing member ballot forms with this issue. Following a meeting of the board to be held in late December, these two candidates will be ratified and the results posted in the Q1 2014 magazine and on the website. We would like to encourage anyone who is interested in participating in the management of the association to start the process by helping us and volunteering, as well as letting us give you the necessary visibility to run as a candidate in the future. We are very fortunate to have two very excellent and experienced candidates this term. They both have great credentials and we know they will be significant contributors to the continued success of your organization. We also want to thank both Karl Bowman and Jim Stitzinger for their help and participation on the management team. We are blessed that they both intend to stay involved and help in the future.. CCA .

Paul Kluwe, W8ZO, is a past President & Member of the CCA Board. He was responsible for many of the improvements in the CCA that have made the recent growth we have enjoyed possible.

Paul has served on numerous boards, founded, grown and then sold his own company, started twelve 501(c)3 foundations, and is currently involved in the development of several charities.

He is an avid Collins and Rockwell Collins collector and feels quite passionate about the importance of preserving the history and technology stories of the company.

Following a brief respite involving a spinout from the 2008 GM breakup, Paul has again expressed his interest in serving the CCA. He is more than welcome back.

Dennis Kidder, W6DQ, has previously served as President, Vice President and Director of one of the most well-known clubs in the world, The Associated Radio Amateurs of Long Beach, W6RO (Queen Mary), and as President of the San Bernardino Microwave Society, a highly specialized, technical group whose mission is to advance communications above 1 GHz.

Professionally he has worked as a hardware designer, software developer and system engineer. He spent the majority of his time at Hughes Aircraft Company (eventually Raytheon) where he worked on programs that did everything from flying satellites to building airports.

Dennis has had his affection for Collins Radio since his first exposure as a twelve-year-old when his *Elmer-to-Be* showed him his station and said; "Collins ... this is the gear you want when you get your license. It's the best." Dennis then bought his first 75S-3 in 1969 and has been fine tuning his Collins knowledge and his station ever since – some 44 years.

CCA Events News

This past quarter has seen the CCA complete its original 2013 goal of expanding the number of official events that we hold around the country from two to five. During Q4, we established our new West Coast Event at **PACIFICON 2013** – holding our first one in the Bay Area. It was a great success and many thanks need to go to the west coast team of Billy Yates (N6YW), Werner Vavken (WB6RAW) and Tom Bonomo (K6AD). Special thanks also to Dennis Kidder, W6DQ, for holding down the fort on Sunday and tearing down when our plans took the setup crew to Southern California. The event could not have happened without them. We had a nice booth right (shown to the right) at the entrance to the show and Friday evening there was the group dinner and talk at Pedro's Restaurant & Cantina and it was a great social time. There was a talk given on the History of Receivers at Collins Radio. The decision has been made by the planning group to have the west coast event each year, but to rotate its location up and down the coast. Keep watching the website - and the 2014 Events Calendar for the announcement of next year's festivities.

ARRL Midwestern, Lebanon, MO

This new CCA event was specially planned around the Lebanon, MO ARRL Convention. The CCA had a very nice double booth and hospitality area donated by the Lebanon Amateur Radio Club, for which we thank them. Scott Kerr, KE1RR, and your editor drove from Wimberley and Dallas and set up shop. The event was our first central Midwestern show and we saw a lot of faces there that could not make Dayton or Dallas. There was a social dinner on Friday night at Dowd's Catfish Restaurant and we had a great time – as always. Big thanks to Scott on this one. The CCA and Electric Radio Magazine co-sponsored the Vintage Radio Beauty Contest and thanks to owner Ray Osterwald, N0DMS, for his donations. See web report for contest photos.

2014 – ORLANDO

Since the ARRL Lebanon show was a one time show, we are taking advantage of this opening and responding to the clamor to hold an East Coast & South Event. We have contracted for space at the Orlando HamCation show (www.hamcation.com) and a nicer and more hospitable group of folks I have never found. The show is February 7-9, 2014 - so it is coming up pretty soon... and gives you East Coast winter folks a chance to go south. We will have a double booth and hospitality the area know as Commercial 3 - Building 2, and then a nice dinner on Friday night where there will be a feature talk and the usual shenanigans and drawings. By the time you get this, information on Orlando 2014 should be up on our new 2014 Events Calendar page on the website – so stay tuned. We hope to see you there. If not Orlando, then perhaps we see you at one of the other shows at Dayton, Dallas, Rochester or California. - - - - - - - - - - - - - - - - - - - CCA - - - - - - - - - - - - - - - - - - -

Avionics at Collins—Then and Now

by **Lawrence Robinson, Curator, Rockwell Collins Museum** - AC12-12658/KC0ODK

Runway 34L was covered in rain on a typical winter day at Paine Field near Seattle. Test pilots, ground engineers, and a large anxious crowd were all forced to wait in the chilly drizzle for the cloud ceiling to lift to acceptable levels. Finally the Rolls Royce Trent 1000 engines spooled up, and the Boeing 787 Dreamliner, carrying the largest amount of Rockwell Collins equipment of any airliner ever (see sidebar), starts to roll on its maiden voyage. It is December 15th, 2009, an impressive landmark in the story of avionics at Rockwell Collins. This story dates back to the early days of Collins Radio. . . . . .

In September of 1934, Collins Radio had been incorporated for just one year. In a letter to "Dear Uncle Newt" Newton Dickenson, dated on the 29th of that month, Merle "MH" Collins writes:

> *There is nothing in the way of "invention" that Arthur has made but he is designing and constructing some very superior transmitting equipment, a large portion of which in dollars goes into the export trade. For instance, we are just completing a very large order of radio equipment for aircraft to be installed in the army planes and frontier land communications stations of the Republic of Columbia, South America."*

The Columbian sale referenced in the "Uncle Newt" letter, valued at $52,677, was the largest order the company had received as of that date. This was serious revenue for a fledgling business, especially given the economic climate of 1934. The Columbia sale, along with a Collins transmitter installed in the Goodyear Blimp "Defender" around the same time, established the company on a trajectory of supplying equipment to both civilian and military aircraft that continues to the present day.

The story of Collins Radio, Rockwell Collins, and avionics could easily consume a book. But for now, let's look at a few other interesting milestones between 1934 and the present day. After the sale of airborne radios to the Columbian military, an important milestone is captured in the following:

> *Arthur was in Dallas again, dining in a restaurant with Tom Braniff, who had founded Braniff Airways in 1930. Braniff told Arthur it was a pain in the neck to have to pay a radio operator to ride along on every flight and do nothing but tune radios. He thought pilots should be able to operate radios. Arthur made some sketches on the tablecloth to show Braniff his Autotune ideas, and when they left he took the tablecloth with him.* 1) From Arthur Collins: *Radio Wizard* by Ben Stearns

The "Autotune" referred to above was an ingenious electro-mechanical control device, capable of moving rotary radio controls to any one of 10 easily programmable preset positions. The first significant Collins product incorporating the Autotune was the Model 17-D transmitter. Braniff Airlines was the launch customer for these revolutionary radios, but Braniff was quickly followed by American Airlines.

Autotune technology continued to be utilized and refined after the 17-D. In 1939 the US Navy, responding to the winds of war, sought a modern airborne transmitter. Ultimately, this need was filled by the famous ATC / ART-13 which represented a quantum leap forward in airborne transmitter technology. In addition to its five Autotune controls, it was notable for its frequency stability which was made possible by the first product implementation of Ted Hunter's new Permeability Tuned Oscillator (PTO).

Long before the war ended, Arthur had set his sights on the coming need for post-war advancements in aircraft electronic equipment of all sorts. Seeking real-estate for a hangar at the Cedar Rapids airport, he wrote;

> *"After the war… equipment will be built for commercial and private airplanes in addition to Army and Navy requirements. It is necessary for this company to establish local facilities for installing and flight testing this equipment in aircraft in order to prove out its designs."*

In another letter composed the very the same day (July 15, 1944), Arthur asked the Pentagon for permission to purchase a test aircraft;

> *"It is necessary… for us to establish local facilities for flight testing and proving our designs by actual installations and use in aircraft. For this purpose we would like to purchase an airplane such as the Beechcraft commercial type 18S… We request your favorable consideration of the allocation of one such airplane…"*

Frank Davis, in a speech to underwriters when Collins made its first public stock offering in late 1944 further revealed Arthur's uncanny ability to see and shape the future of technology*: "We expect to expand our work in this field, but airplanes and their associated ground control stations need electronic equipment for purposes other than communication. This may include direction finders, beacon receivers, marker receivers, localizer receivers, blind landing equipment, altimeters and many types of radar and related equipment. Some or all of these may be carried in the airplane. In addition there is corresponding equipment for the ground part of the system. We plan to develop and manufacture such items of equipment where we feel we can make some improvement in performance or worthwhile contribution to the design."* 1)

Avionics—This is where it may have started

The following passage recounts Roy Olson's story of the radio he designed for Arthur's first airplane, a Rearwin Sportster. Olson and Collins took delivery of that aircraft in October of 1936.

Olson recalled that the weather was warm when they went to Kansas City, Kansas, but when they were ready to start home on a Sunday afternoon they learned a cold front and snowstorm were moving toward Cedar Rapids. They borrowed cold weather flight clothing from the aircraft factory and took off.

The new radio proved to be a good unit, with a trailing wire antenna, let out to the appropriate length to match the desired frequency. When they got within range, contact was made with the Civil Aeronautics Administration ground station at Davenport. At one point the station operator asked: "What type of aircraft are you? You have such a strong signal we thought you must be an airliner of some kind." Olson recalled.

As they neared Cedar Rapids, with Olson flying and Arthur operating the radio, they ran into the snow storm about 30 miles southwest of the city. Olson remembered that while Arthur was on the radio talking about a possible landing at Iowa City, he flew on, passing over downtown Cedar Rapids about the height of the tallest buildings, and made a safe landing at the Hunter airfield.

Roy Olson said it was about that time that Arthur decided Collins Radio Company should become the main source for commercial aircraft equipment, because he saw a good markup in building and selling to airlines. 1)

A Beech 18 was acquired and the hanger - built as a result of the 1944 letter - remains in use by Rockwell Collins to the present day. Arthur's vision of the future, painted by Frank Davis for the investment community, quickly became reality for the company and has remained so for more than six decades. The continuous stream of airborne radio innovation (both military and commercial) also continues to the present day and is deserving of its own article. This list includes the ARC-27 (the first "modern" UHF tactical radio) along with HF radios such as the 18S, 618S, the ARC-58 (the first SSB radio designed exclusively for airborne use), and the 618-T, a commercial follow-on to the ARC-58. The 618-T, representing the company's successful campaign to drive SSB technology into the commercial market, became ubiquitous for airliners around the world - remaining in wide use for decades. A steady stream of military airborne radios followed the ARC-27 (designed in 1946) leading up to the ARC-210, found today on virtually every US Navy and Marine aircraft.

Frank Davis told the investment community, *"Airplanes and their associated ground control stations need electronic equipment for purposes other than communication".*

The organic aspect of how Arthur brought this vision into reality involves a think-tank of geniuses such as Walter Wirkler, Alexander Lippisch, Horst Schweighofer, Rolf Wollan, Francis Mosely, John Shanklin, Marvin Moody and others. Collins "bet the company" on productizing the emerging standard for Very-High-Frequency Omnidirectional Range (VOR) technology, becoming the first company to achieve CAA certification on an Air Transport VOR system. Two seminal patents, applied for in 1951, and now known as the Horizontal Situation Indicator (HSI) and the Flight Director (FD) firmly established the company's leadership role in flight instrumentation technology. Arthur Collins' name appears on both patents as co-inventor, along with Horst Schweighofer for the HSI and Rolf Wollan on the FD. Wirkler's breakthrough, "Aircraft Course Stabilizing Means" patent, applied for in 1949, defined what would became known as the "Complementary Filter". It describes analog computing techniques for creating steering commands enabling either human pilots (through steering instructions presented on the Flight Director), or autopilot systems, to execute smooth intercepts of electronic navigation signals (outer loop flight control). The Collins "V Bar" Flight Director became popular in the early 1960s. (See DC-6 to left) The FD and HSI products were intricate electro-mechanical designs, assembled in clean rooms with watchmaker precision. Like the 618-T, SSB airborne transmitters and HSI/FD systems (such as the FD-108 and FD-109) became ubiquitous, spawning many copies from competitors. To students of Arthur Collins and his post-war innovation machine, there is no surprise that due to their intuitive and elegant presentation, the HSI and FD motifs remain the industry standard for advanced flight instrumentation systems, even in the most modern glass cockpits.

All three of the patents discussed, along with many others, we're signed by Marvin Moody, who joined Collins Radio as patent attorney in 1949. Trained as a Hellcat Pilot by the US Navy during WWII, then completing an Electrical Engineering degree prior to law school, Moody's resume gave him the perfect profile for his role in the innovation factory that was Collins Radio. Moody left the company on good terms to enter private practice in the Chicago area where he still resides with his wife, Alice.

The flight director work also spawned a number of business aircraft autopilots in the '50s and '60s, but no larger airliner autopilots. That changed when Collins partnered with Lear-Siegler to create the Auto Flight Control System (AFCS), which included *fail-operational* automatic landing capability for the Lockheed L-1011. This was to be the last major avionics innovation while Arthur was leading the company. The AFCS was the first fully-automatic Category III "Auto-land" system to achieve FAA certification as part of a basic aircraft type certification. Although commercial popularity of the L-1011 was marginal, the AFCS success, combined with Collins' internal R&D advances, led directly to future autopilot systems on a long list of larger platforms, including regional jets and large airliners. For example, Boeing airplanes featuring Collins autopilot / automatic landing systems include the 767, 757, 747-400, 747-8, recent 737s, and the 777.

Digital technology and smaller microprocessors finally drove a purely electronic, CRT-based solution for primary flight and navigation displays. In the 1970s, Collins was selected by Boeing to create the "glass" EFIS, (Electronic Flight Instrumentation System) for the 757/767 flight decks. This project also marked the introduction of the Engine Indicating and Crew Alerting System (EICAS). During the 1980s, Rockwell Collins was successful in steering its customers away from the electro-mechanical FD-108, 109 and derivative systems to "glass" (CRT) systems such as the EFIS-85 for business and regional

aircraft. The industry soon realized there was a need for ever more integration in the flight deck as well as in the "black boxes"

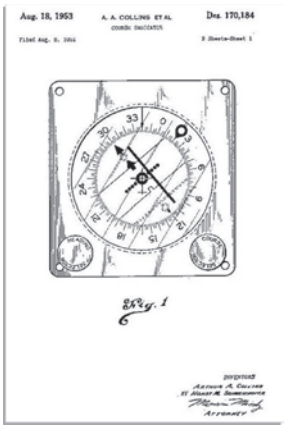
The Beechcraft Starship (above), in development during the 1980s, boasted the first highly integrated glass cockpit with 14 CRTs in the flight deck. Rockwell Collins' Integrated Avionics Processing System (IAPS) was a paradigm shift approach that combined functionality, previously requiring numerous individual "black boxes", into a single "cabinet" architecture bringing advantages in size, weight, power, and cost. This architecture evolved into the Rockwell Collins Pro Line 4 and Pro Line 21 systems which have found their way into numerous models of business and regional jet aircraft. Examples include the Canadair Regional Jet (models 100, 200 and 700), The Dassault Falcon 2000, Learjet 55, Gulfstream G-150, and the Beechcraft Premier 1. Pro Line 21's "Integrated Flight Information System" (IFIS) was the first avionics system to integrate features such as ground-sourced weather graphics, electronic approach charts, enroute navigation maps, and 2D terrain maps into the main flight deck displays.

Formula One racing legend and airline magnate Niki Lauda took delivery of a brand new Bombardier Global 5000 on March 30th, 2012 - the first airplane to enter service with Rockwell Collins' latest flight deck architecture: Pro Line Fusion™. With emphasis on common computing resources, as opposed to application-specific hardware, Pro Line Fusion raises the bar in design flexibility, making its feature-rich software capable of serving large variations of flight deck layouts and aircraft size. New features offered such as an integrated Heads-Up Guidance System (HGS™), synthetic and enhanced vision, graphical cursor control of display features including pilot-customizable sizing, touch-enabled main displays and windowing features, combine with legacy features such as IFIS and MultiScan Threat Detection Weather Radar System to make the flight deck of the future. The list of publicly announced aircraft that have selected the Pro Line Fusion™ flight deck include the Agusta Westland AW609 Tiltrotor, Bombardier's Global Series 5000 through 8000; Learjet 85, CSeries; Embraer's Legacy 450, Legacy 500 and KC-390 refueling tanker; Gulfstream's G280, and the Mitsubishi Regional Jet (MRJ). . . . Back to Paine Field . . . .

. . . . .Up front, in the business end of the new Dreamliner, a short phrase buried in a steady stream of chatter from the VHF-2100s brings us back to the task at hand. "… Zero-zero-one, you're cleared for takeoff". Then, all eyes forward, the big Boeing starts to roll and takes the runway. One can almost see the shadow of a graying older man sitting in the jump seat. Leaning forward, he is smiling - but he is not surprised. He knows the flight will go smoothly. - - - - CCA - - - -

Marvin Moody - Patent Attorney (retired)

Marvin sits and ponders advances that he helped patent well over 60 years ago on August 18, 1953. He marvels at the fact that the HSI (and Flight Director) motifs that were developed by Collins Radio in the 50s are still in use today—even in the "Glass Cockpit" era. M. Moody served, first our country as an F6F pilot during WW II, and then as a Patent Attorney for Collins from 1949 until he left for private practice in 1967. He also has a EE Degree from Iowa State enabling him to well understand the issues he was prosecuting for these patents.



Navigation Advancements

Navigation technology evolved in parallel with the flight decks. As part of this evolution, one July night, a young engineer found himself stationed on the roof of Rockwell Collins' building 106. It was his job to, every five minutes, manually aim a "junk-box" L-Band antenna (a subcontractor had not yet delivered the exotic high-tech antenna) in tests of a new navigation system. A bootleg telephone line was strung to the youngster's rooftop perch so his wife could reach him if she needed to be taken to the hospital to deliver their second child. In this manner, Rockwell Collins received and decoded the first "NAVSTAR" (GPS) signal at 11:35 PM CDT on July 19, 1977. The engineer's second child, a daughter, was successfully delivered on August 6th. In 1983, Rockwell Collins made the first transatlantic flight utilizing GPS navigation. Flight legs were limited to 2 or 3 hours due to the small size of the GPS constellation at the time. Landing at the Paris Air Show, the record-making flight was also the first use of differential GPS when a local offset was radioed to the aircraft shortly before landing. Upon landing the aircraft even used GPS exclusively to taxi to its predetermined parking space. Flash forward to this century……

During Operation Desert Storm, it is believed that Rockwell Collins GPS equipped MH-53's "Guides" assisted the initial waves of Apache Attack Helos (with no GPS) to squash air defenses that first night. Today, tens of thousands of Rockwell Collins hand-held (PLGR and DAGR) GPS receivers have been delivered to the US DoD. More recently, the Rockwell Collins Digital Integrated GPS Anti-jam Receiver (DIGAR) was selected by the US Navy for the Joint Precision Approach and Landing System (JPALS). According to *USNI News* article dated November 22, 2013, the "U.S. Navy has completed the initial development of the Joint Precision Approach and Landing System". Quoting NAVAIR spokeswoman Marcia Hart, the article describes, "Highly successful shipboard auto-land testing on USS Theodore Roosevelt (CVN-71)," and emphasizes the specific demonstration of the system's ability to support automatic "hands-off" landing – with GPS.

Rockwell Collins Content - Boeing 787 Dreamliner

During the 787's development and design process, *Rockwell Collins* served on Boeing's 787 Partner Council and had employees working onsite at the Boeing facility participating in day-to-day program design, integration and production activities. Rockwell Collins provides the following systems for the 787.

Components Supplied

* An integrated display system featuring five 15.1-inch diagonal LCD displays, as well as dual LCD head-up displays (HUD). The Rockwell Collins Head-up Guidance System (HGS™) provides the most advanced display capabilities available in the air transport market, including primary flight, advanced navigation and complete crew alerting functionality. The system utilizes cursor control devices and a multi-function key pad for data entry and retrieval.

* Rockwell Collins VHF-2100, SAT-2100 and HFS 900D state-of-the-art communications capabilities including the lighter weight, highly reliable VHF-2100 that is VDL Mode 2 capable with future growth to VDL Mode 3 and 4. The new, smaller and more reliable SAT-2100 supports the International Civil Aviation Organization's safety services, as well as three channels of voice communications and offers growth to support future Inmarsat Swift Broadband high-speed data capabilities. As part of the communications package, Rockwell Collins is also providing a state of the art digital flight deck audio system, and the cockpit voice and flight data recording system.

* Rockwell Collins' newly developed Integrated Surveillance System (ISS) including weather and hazard detection, traffic alert and collision avoidance, Mode S surveillance, and terrain awareness and warning capabilities.

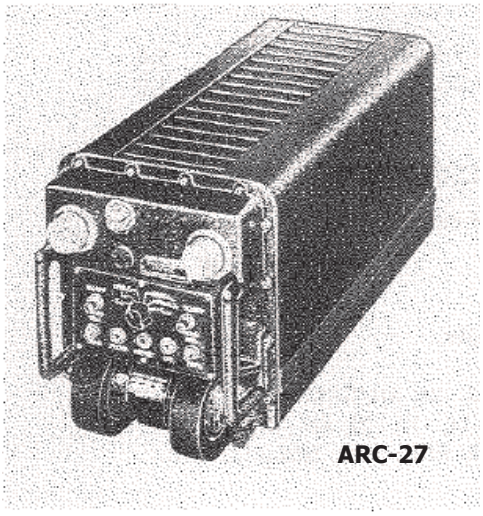
* The latest generation of pilot controls with a control stand that includes auto throttles, and pitch, roll, yaw and primary flight controls, as well as their interfaces to the aircraft's fly-by-wire systems. The modular design of the pilot controls will simplify installation and maintenance. This new system meets Boeing's objective of providing operators with a look and feel similar to the Boeing 777, while achieving significant weight savings. This was a key factor in allowing Boeing to achieve dual type rating certification for the two aircraft.

* The Core Network, offered as standard on the 787, which plays a key role in Boeing's objective to 'e-enable' the entire aircraft. Utilizing commercial open standard computing servers and networks, the Core Network hosts a wide range of third-party applications and manages onboard information flow to improve airline operational efficiency.

* The Common Data Network (CDN), which advances Rockwell Collins' leadership as a supplier of advanced networking technologies. As a key component of the 787 Common Core System, the CDN is a high integrity, bi-directional fibre optic and copper network that uses ARINC 664 protocols and standards to manage the information flow between the aircraft's onboard systems. Based on commercial Ethernet technology adapted to the Avionics environment, the integrity and deterministic characteristics of Rockwell Collins' CDN allows systems integrators to utilize this network for systems requiring a high level of data criticality. The CDN offers significant improvements over current generation data buses including expanded connectivity, higher data rates and significant reductions in aircraft weight when compared with point to point topologies.

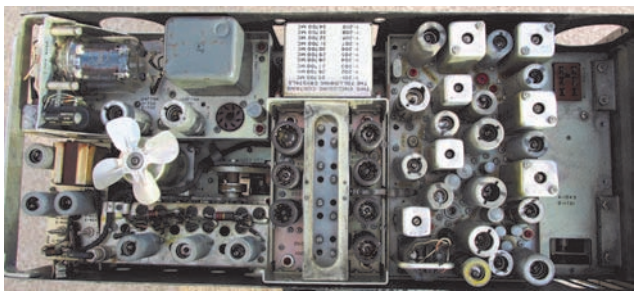
Airborne UHF Comm at Collins Radio
- An Overview -

by **Scott Johnson, W7SVJ** - AC04-11696



It was abundantly clear during the closing days of World War II that tactical military aircraft communications was at a crossroads. Air power had grown by leaps and bounds, and with the airlines and the air traffic control systems of the world committed to VHF (118-136 MHz), the military needed to occupy new, wider spectrum to accommodate operations. The high VHF/low UHF range (225-400 MHz) had been contemplated, but government funding for equipment development had been halted with the surrender of Japan. The advantages of what would be called "UHF" in the tactical aircraft communications sense were clear: 175 MHz of bandwidth, which in the early years would net 1750 discrete channels; freedom from interference, both manmade and atmospheric; and finally, because of the relatively low power and line-of-sight propagation characteristics, a measure of security. An added bonus was physically small, low drag antennas, which was requisite with the new generation of jet powered aircraft that were simultaneously being developed.

Western Electric had led in the development of VHF and UHF communications during World War II. An early example is the AN/ARC-4 VHF set (WE-233) which was a pre-war design commissioned for the airlines and then pressed into naval and USAAF service in the pacific. A later (1944) effort was the AN/ARC-1 ten channel VHF set utilized by the US Navy - and in service until the early seventies. The ARC-1 was followed by the ARC-12, which seems to have seen the light of day in about 1947. The AN/ARC-12 was essentially a UHF version of the ARC-1, even sharing the same rack and control box. These radios formed the impetus for the AN/ARC-19, a product of the Naval Research Laboratories, which covered the 225-400 MHz range in 876 channels, spaced 200 KHz apart. Ten preset frequencies could be readily selected. Power output was a nominal 4 watts, and receiver sensitivity was 20 uV. Simultaneously to the work being done by the Navy, Bendix was working on a UHF radio design for the USAAF that would be introduced as the AN/ARC-33 sometime around 1949. Collins picked up the ARC-19 design, and endeavored to turn it into a manufacturable, much improved, model that would sustain the US and allied militaries for years to come. That model would become the AN/ARC-27, and the most produced military aircraft radio of the post war era.



The ARC-27 (figure 1a - above & 1b) was quite a marvel of miniaturization for the time. Collins managed to pack a complete transceiver capable of operating on 1750 discrete channels from 225 to 399.9 MHz into a package that was less than 2 cubic feet and weighed in around 72 pounds. For the first time, all channels were available to the aircrew, and 18 preset channels could be set by the crew with no assistance from ground radio technicians. Internally, the ARC-27 is arranged into eleven functional modules, easily removable with captive screws. In practice, most modules could be replaced without realigning the radio, which made servicing relatively easy. The ARC-27 employs a crystal mixing scheme employing only twenty crystal total to synthesize 1750 channels (not counting the few injection oscillator mixing crystals for down-conversion in the receivers). A spectrum oscillator provides a frequency comb for mixing in both receive and transmit. Power output is 8-10 watts from a three stage power amplifier employing a 2C43 pre-driver, and 2C39 driver and PA. Modulation is via an 829B through an autotransformer type modulation reactor. The ARC-27 employs an independent guard receiver (normally crystalled to 243.0 MHz), which has its own IF and detector stages. Only guard audio is common with the main receiver.

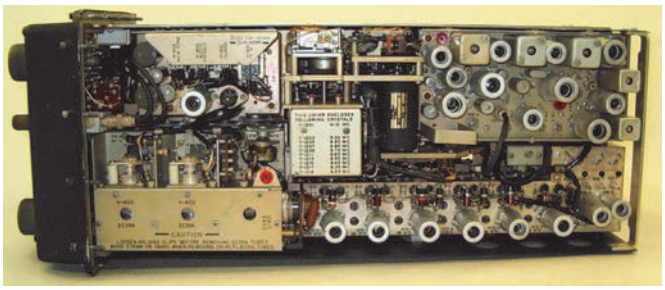


Figure 1b - ARC-27 Top View (open)

Early on, the ARC-27 configuration was rather clumsy, having two control units, the C-626 (shown top of next column), which used auto positioners to store eighteen preset frequencies, and the C-625, which allowed the pilot to select those presets.

Figure 3 - C-1904

The C-626 was typically mounted in an out-of-the-way space, which in the case of fighters meant out of the pilot's reach. Later, additional control units were developed that allowed direct frequency selection and programming of preset channels, the most common and compact being the C-1904 (See Figure 3 above).

The ARC-27 was in service long enough to receive the usual modifications that improved performance and/or reliability. Chief among those was the PP-2100 solid state power supply that replaced the dynamotor. This had the effect of lowering power consumption, internal heat, and eliminating the troublesome carbon brush dust from the sealed case. A solid state guard receiver was also procured in the early sixties, but use was not widespread. Later production also had improved coupling and bypass capacitors in the RF sections. A non-pressurized, cost reduced version was produced for the US Army as the ARC-55. The ARC-27, with all of its modifications and updates, soldiered on well into the seventies, although not in front line tactical aircraft. Ground variants of the ARC-27, such as the AN/GRC-32 would see use around the world well into the eighties!

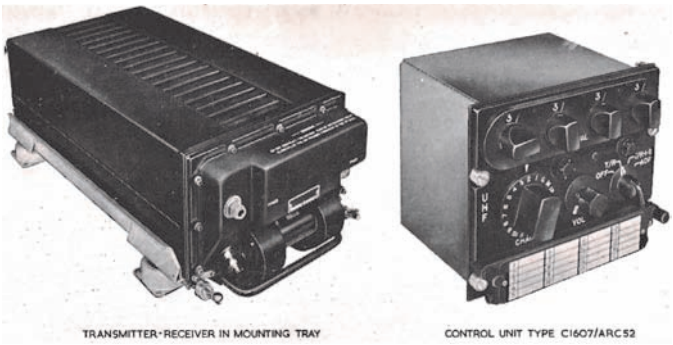


Figure 4 - ARC-52 Developed for the NAVY in 1952 and manufactured until circa 1963

By the mid 1950s, the requirement for higher reliability, lighter and more compact equipment was starting to render the ARC-27 obsolete. Work was proceeding on the US Navy's AN/ARC-52 (figure 4), which looked much like a miniaturized ARC-27, but with a few fundamental differences. The biggest was the inclusion of the revolutionary Hubbard coaxial tuners which were then driven by a massively complex gear train. These tuners added to complexity, but were compact and had very high "Q". The ARC-52 also featured uniform modular construction and employed Oldham couplers to facilitate decoupling the mechanical assemblies. Another fundamental change was the use of a single high gain cermet tetrode in the final amplifier stage. The resulting Collins designed ARC-52 became the Navy's standard UHF transceiver from the late fifties through the mid-Vietnam era. (The USAF had chosen the Magnavox AN/ARC-34).

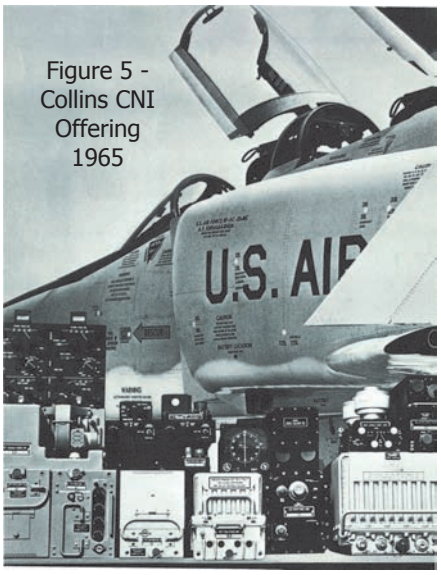


Figure 5 - Collins CNI Offering 1965

At almost the same time as the ARC-52 was being finished up, work was also proceeding on a transistorized UHF transceiver for the USAF and US Army that was even more compact than the ARC-52.

This would enter service as the ARC-51 but never achieve the high volume production of the ARC-52. Both the ARC-51 and ARC-52 modules would form the basis of the communications elements for the various CNI (Communications/ Navigation/Identification) systems Collins was developing for the century series fighters for the USAF and new generation naval fighters (See Figure 5 below left column).

By the sixties, solid state technology had become more mature, and the majority of a radio's circuitry could be produced using transistors. In order to further reduce volume and weight, Collins produced a plethora of hybrid integrated circuit modules, usually a functional block, these little black cubes were made as amplifiers, limiters, squelch circuits, and digital functions, just to name a few. The next generation of Collins UHF radios would benefit from the inclusion of the modules, namely the AN/ARC-109. (See Figure 6a)

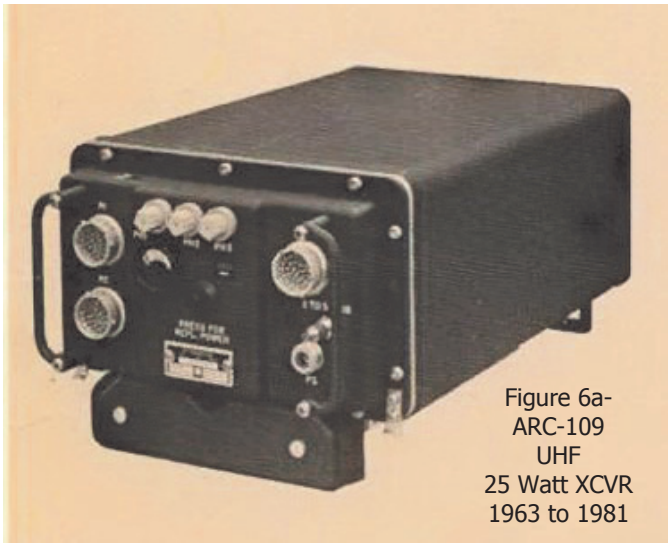


Figure 6a- ARC-109 UHF 25 Watt XCVR 1963 to 1981

The ARC-109 was a high water mark in UHF communications, and was installed in the F-111, C-5, and F-15/16, all new designs out of the late sixties. It was lighter and more compact than the ARC-51, and boasted the highest output power for a UHF airborne transceiver to date, at typically 25-30 watts. The ARC-109 saw the reduction in the number of mechanical tuning assemblies in the radio due to broadband circuitry in low level stages and in the frequency synthesizer. With 3500 channels spaced at 50 KHz increments, it was a marvelous job of engineering. Preset channels are stored in the C-6364 (Figure 6b) control head in nonvolatile magnetic core memory. Later units even had early seven segment digital frequency readouts of the incandescent filament variety. The ARC-109 would be the last series of Collins UHF aircraft radio to utilize a vacuum tube in the final amplifier and, based on its modular architecture, would form the basis for the Naval Growth Radio program in the late sixties and seventies.

Figure 6b - C-6364 ARC-109 Control Head

The early seventies saw a new generation of war fighting machines, with orders of magnitude more computing power for comm, weapons direction, and navigation. Aircraft such as the F-14 Tomcat leveraged much of this technology, and to ease the crew's workload, man machine interfaces needed to improve.

Centerfold Credit: Rockwell Collins Pro Line - Fusion ™ - Product Line. Photo provided by Rockwell Collins, Inc. Read about the install aircraft in this issue's Avionics article.

Continued on p 44


CVS
HUD
ROLL SPLRS
MASTER WARNING/CAUTION
PUSH/EVS CAL
PUSH/MODE
PLT CONT
Rockwell Collins
HDG
AP2
ALTS
LIM
SPD
TAS 235
GS 237
HAND MIC
SPEAKER
ON
OFF
MODE
TAWS
GS
FLAPS
TERRAIN
RUNWAY
DC ELEC
AC BUS 2


IAS 250
HDG 158
6000
VHF1
118.050
126.350
NAV1
109.50
115.70
ATC/TCAS
5606
AUTO
NEXT PAGE
TUNE/DATA

The Service Line

30L-1 INSTABILITY - Cause & Cure

by **Don Jackson, W5QN** - AC03-11523

Recently some stability issues with the 30L-1 have come to light and been discussed on the CCA reflector. The problems were brought up by Dave Harmon, K6XYZ, and Rick Williams, W1RIK, who have both experienced stability problems with the 30L-1 on 10m, 15m - or both. Dave, an experienced Collins technician, has two 30L-1s that are unstable on 15m and 10m, so there has to be something going on here. Becoming curious, I began some experiments with my own WE 30L-1 and found two independent oscillation scenarios.

Scenario #1: HF Oscillation - The Hi-Res Communications 30L-1 video mentions this problem. Section 1 has this statement concerning the 20.5 foot RF cable originally supplied for use with 30L-1s: "This length was determined through comprehensive laboratory testing at Collins to reduce instabilities between the exciter and amplifier. This is especially important with earlier amplifiers but is recommended with all 30L-1s." Dennis Brothers concurred, but said Collins changed the 30L-1 input matching components to eliminate the need for the long cable.

It is known that the original application of the 20.5 foot cable was to improve IMD in a specific system using a KWM-2 (or 32S-X) driving the 30S -1 amplifier. The theory behind use of the 20.5 foot cable with the 30L-1 is not clear, but it is unlikely that it was just intended to improve IMD since the cable would have to be a different length to simply account for the phase delay difference between the 30L-1 & 30S-1 matching networks. Apparently, however, the cable also improved 30L-1 stability. My belief is that there is probably nothing magic about the exact 20.5 foot length, but engineers found that this cable improved 30L-1 stability when Collins exciters were used. The cable already had a part number and was in stock, so they used it. Sometime later, engineers changed the input matching networks so that the 20.5 foot cable was no longer needed, but I do not have knowledge of details and timing of component changes. I've noticed that some of the input network inductances are different in the 5th and 8th edition manuals. Also, the wiring diagrams in the 5th edition refers to the 20.5 ft cable, but the 8th edition doesn't. So, it may be that these inductance changes were associated with the cable elimination. If anyone has more knowledge of this, please let me know.

I ran a couple of tests on my own 30L-1 (WE), which has Cetron 572Bs installed. I had never noticed any stability issues with this amplifier on any band during normal operation, but had never looked very hard. First, I terminated the 30L-1 output and input ports with dummy loads. I then keyed the amplifier (without RF drive) and observed the plate current while varying the Tune and Tune controls randomly in an effort to cover every possible combination of settings. If the amplifier breaks into oscillation, you should see the plate current move. As well, I also monitored with a spectrum analyzer. During this test I never saw any sign of oscillation. Next, I repeated the test with my 32S-3 connected to the input (using 4 ft cable), and then again with the 30L-1 input unterminated. In none of these cases did I detect any oscillation. For the next test, I created a worst-case scenario in which both the input and output circuit were left unterminated. The idea of leaving the output unterminated made me very nervous, but Dave said he had done this and as long as any oscillatory condition was allowed to last for only a second or so, there would be no harm. So, I gritted my teeth and tried it. I found that my 30L-1 did oscillate on 15m when the Tune control was set to around 9.7 or so. Although I saw no instability on 10m, others do. The oscillation was present no matter what the Tune control setting was. The oscillating frequency was always in the neighborhood of 26 MHz. Next I tried the same test but with a 50Ω termination on the input only. The oscillation, similar to Dave's, was still present, appearing about the same as with the input unterminated.

To ensure that this oscillation was not an anomaly unique to my 30L-1, I borrowed Bob Kellow's (W5LT) 30L-1, which is a WE unit with 811A tubes installed. It too, displayed the same oscillation although at the slightly lower frequency of 23 MHz. From all the data gathered over several months, it is clear that the 30L-1 is not unconditionally stable. An "unconditionally stable" amplifier is one that will not oscillate under any combination of input/output complex impedances. However, there may be only a single set of input/output terminations and Tune/Tune settings that enable a particular 30L-1 to oscillate. Another unit may oscillate under a different set of conditions. In any case, it is fairly clear that Collins did not design the 30L-1 with unconditional stability as a necessary goal. The manual specifies that it not be operated with an output load VSWR worse than 2:1, which usually takes care of HF instability, as well as making sure the amplifier is not damaged by operating into a bad load. The most important item to ensure HF stability is a good termination on the 30L--1 output at the operating frequency, but even that was not enough in the case of Dave's unit, which required a length of cable on its input port. Perhaps this is what Collins engineers first noticed and why they initially called out use of the 20.5 foot cable connecting the 32S-3 to the 30L-1.

Tom Rauch, W8JI (designer of the Ameritron AL811 amplifier), is a fan of neutralizing grounded grid amplifiers designed with 811A tubes. Typically, neutralization is used to cancel out the plate-to-grid feedback capacitance in grid-driven, common cathode amplifiers. Grounded grid amplifiers usually do not require neutralization because a truly grounded grid provides isolation between the plate and the cathode. However, the 811A has undesirably long internal leads, and the 30L-1 grids are not truly grounded. For these reasons, neutralization of the plate-to-cathode feedback might be helpful in improving HF stability. It appears that neutralization could conceivably be added to the 30L-1, although a hole in the tube socket mounting plate would be required. However, neutralization of the 30L-1 isn't really necessary if you ensure that a good load is provided at the output port. Go to www.w8ji.com to read what Tom has to say on the subject.

Scenario #2: MF (Medium Frequency) Oscillation - During my normal shack operation, a second 30L-1 stability issue surfaced. While monitoring the output of my 30L-1 with an oscilloscope during normal 15m operation, I noticed a low-level signal (about 15V peak) that would pop up when the PTT was activated, but no RF drive applied. Further inspection revealed a periodic burst oscillation. The burst rate was synchronous with the AC line frequency. The oscillation frequency was about 800 kHz. Figure 1 is a photo of the waveform with a horizontal scale of 2ms/division. Notice that although the 800 kHz bursts occur at a 120 Hz rate, the true envelope frequency is 60 Hz. The difference in alternating peak shape was eventually determined to be caused by interaction of the 120 Hz HV supply ripple and the 60 Hz grid bias ripple.

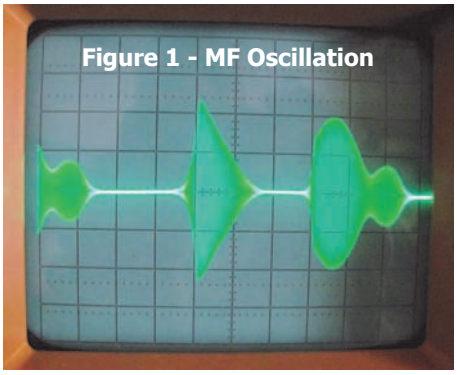


Figure 1 - MF Oscillation

At first I assumed this was an anomaly unique to my 30L-1, but after consulting with Bob Jefferis (KF6BC) and Dick Weber (K5IU), this was not the case. All units we checked out (5 in all, some with 811A and some with 572B tubes) exhibited the same basic phenomenon. In my unit, experiments showed that the oscillation was present even with a broadband 50Ω input

termination, but was somewhat dependent on output load. The oscillation was not present with a broadband dummy load, or with my 15m dipole antenna, but did occur with my 15m vertical antenna. This was initially puzzling since both antennas had excellent VSWR on 15m. I then realized that the dipole antenna included a voltage balun which is a DC short at the antenna feedpoint, whereas the vertical has a current balun, which is a DC open, so there was likely to be a significant impedance difference at medium frequencies. This medium frequency oscillation (MFO) is more troubling to me than the HF oscillation of Scenario #1 because it can occur even when the 30L-1 is terminated with an antenna having low VSWR at the desired operating frequency. How many antennas do we use that have good VSWR in the medium frequency band? It wouldn't be much of a stretch to say the answer is "zero". I turned on an AM radio, and sure enough, I was transmitting a loud buzzy signal at 800kHz when I keyed the PTT.

From initial experiments, it appeared likely that the 30L-1 needed to have a low impedance output termination at low (around 800kHz) frequencies in order to suppress this oscillation. I constructed a highpass-lowpass diplexer network for the 30L-1 output to test the theory. This network provides a 50Ω termination at frequencies below 2MHz, without interfering with the normal antenna termination impedance at the operating frequency. This approach worked well, eliminating the undesired oscillation. A schematic of the diplexer is shown in Figure 2 and a photo of the "junk box" diplexer is shown in Figure 3. The diplexer design was generated using free software available at www.tonnesoftware.com.

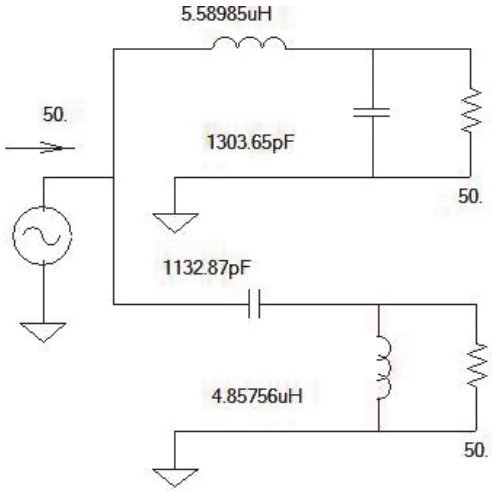


Figure 2 – Diplexer Schematic (Left)

However, although the diplexer approach works well, it requires building an add-on assembly, and is only suggested as a possibility for those who really do not wish to modify their 30L-1. For the rest of us, a 30L-1 internal modification would be a better solution.

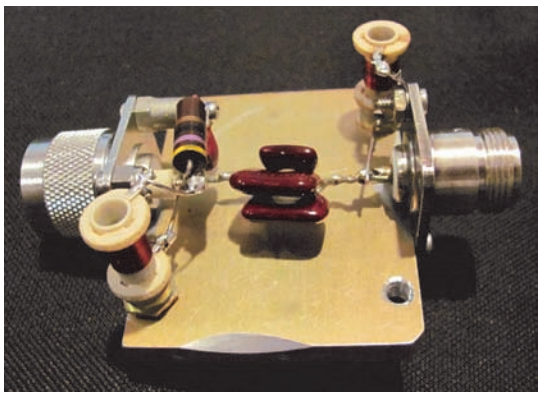


Figure 3– Diplexer (Above)

At this point, the team of Bob, Dick and I set about determining the cause of this oscillation. Looking at the schematic diagram of the 30L-1, it didn't take long to realize that if the circuit was viewed at medium frequencies, it looked much like a Tuned Input Tuned Output, common cathode oscillator. The grid is tuned to about 860 kHz by L3 (39uH) and the four grid bypass capacitors, each having a value o 220pF. Meanwhile, the plate resonant frequency is set primarily by the plate choke L12 (44uH), blocking cap C31 (1000pF), and the Tune and Load variables, C32 and C33. With the 30L-1 RF output port terminated in a high impedance in the medium frequency range, a rough calculation of the plate resonant frequency revealed it can be varied from about 900 kHz to 2.9 MHz, depending on band and the settings of the Tune and Load controls. Feedback for the oscillation is provided by the plate-grid parasitic capacitance (Cpg) of the 811A tubes. Each tube has a Cpg of 5.6 pF resulting in a total feedback of 22.4 pF. This was enough of a "smoking gun" to investigate the TITO oscillation mechanism further.
A Spice simulation was created using the best 811A tube model I could find on the web. Sure enough, the Spice model oscillated just as in the real world. Using the model, it was clear that the oscillation could be stopped by changing the grid choke (L3) characteristics. L3 is 39 uH in most units, but is 22 uH in some later units. Fortunately, Dick has a 30L-1 with the 22 uH choke, and it displayed the MFO as well. One strategy to quell the oscillation was to increase the value of L3 to lower the grid resonance to a frequency well below the lowest possible plate resonance. However, by itself, this was an impractical solution, because an L3 with sufficiently high inductance created self-resonant frequency (SRF) issues with actual components. It was then found that placing a resistor (Rp) in parallel with L3 stopped the oscillation. Unfortunately, the initial Spice model just showed a "go or no-go" state for the MFO. What we needed was a technique to quantify the level of stability improvement for each of many possible choices for L3 and Rp.

A very successful technique was provided by a modification of the Spice model in which the amplifier/feedback loop was opened up, and the open-loop gain and phase characteristics investigated. This is a classic technique often used in the stability analysis of operational amplifiers, but can be applied to any feedback system. As we know, a feedback system will be unstable if the voltage gain around the loop is unity (or greater) at a frequency in which the phase shift is zero, or a multiple of 360º. In the Spice simulation, the gain at zero degrees phase shift was recorded for a wide range of L3 and Rp values. This gain/phase analysis was a consistent predictor of oscillation when L3/Rp values were installed in actual units. Just as importance, the "gain margin" for each set of components quantified the degree of stability for each L3/Rp combination.
Using this information, it was determined that an L3 value of 56 uH and an Rp of about 3k should do the trick, even in the worst-case scenario of 30L-1 tuning and input/output termination. All five 30L-1s were modified with these values. In every case, the MFO could not be reproduced under any tuning or termination conditions.

The MFO Fix

The new 56 uH choke can't be your typical molded choke. After considerable research, I found the Epcos 82111EC24, a choke that has a self resonant frequency (SRF) of 70 MHz, well above the HF operating band. I measured its SRF, and found it to be 77 MHz. The resistor value, Rp, isn't critical, and can be 3.3k if you wish. Although 1/4W dissipation value should be enough, Bob and I used 3.3k 1/2W because we happened to have some on hand, and Dick used a 3k, 1W. Be sure to use a carbon composition, or a low inductance film design.

For space reasons, Bob suggested mounting the resistor on the choke leads before installing. This makes the job a lot easier as the terminals for connecting L3 are already crowded. Figures 4 and 5 are Bob's "before" and "after" installation photos. You can also see the Littelfuse TZS Diode (20KPA204CA) grid protection device. Bill Carns highly recommends installing this device (the TZS is recommended over the MOV) in his 1st Qtr 2010 Signal article. The Littelfuse TZS Diode and Epcos choke are both available from Mouser.

While you have the 30L-1 opened up, I would suggest checking out R28. As mentioned by WB7ODD recently on the CCA reflector, this resistor is underrated at 1/2W when drive is applied to the 30L-1. It should be replaced with a 1W or 2W resistor.

Continued on p 45

HF-80 MY STORY

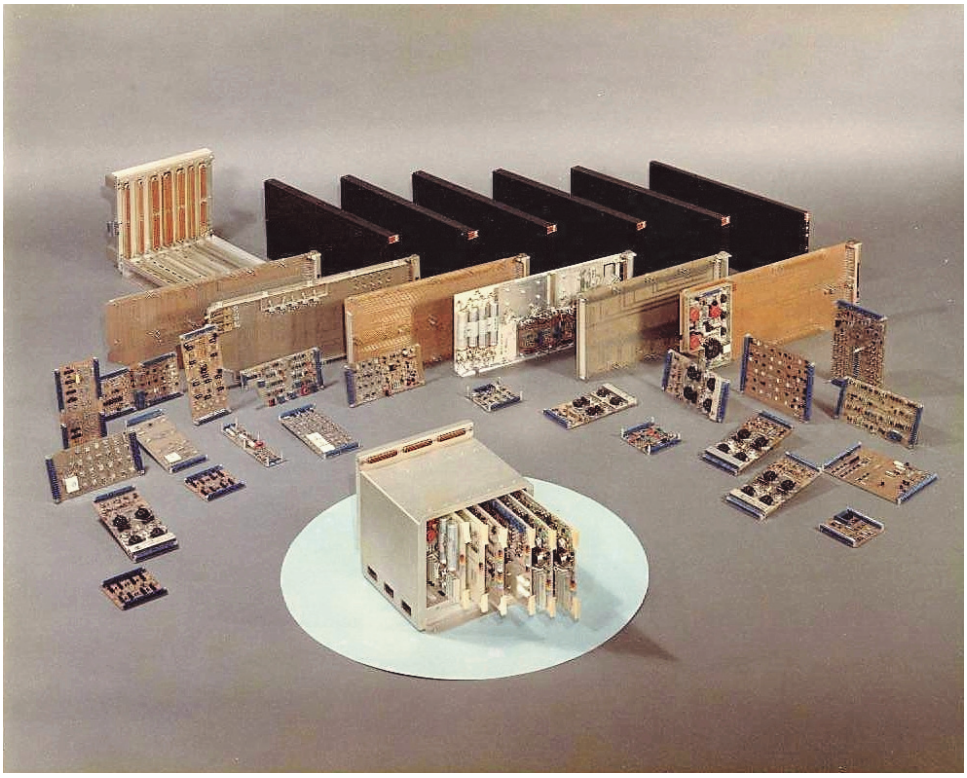
Background

In January of 1974 I returned to Collins after an extended leave of absence for military service and a year of graduate school. During my absence Collins Radio Company had gone through a dark financial period and was now emerging as the Collins Division of Rockwell International. By some stroke of fate, I missed all the trauma at Collins during those years and at the same time accumulated a wealth of experience in USAF Communications Systems (much of it using Collins equipment) and a fresh MSEE degree. My earlier experiences at Collins Radio had convinced me that this was the company for me, and further - that I wanted a crack at joining the HF design engineering department. After my return, this was exactly where I found myself - in the HF Power Amplifier group of the HF Engineering Department headed by Dennis Day, W0ECK.

Years earlier I had met Dennis and several other seasoned HF design engineers and was impressed with their knowledge and skills, and particularly their willingness to take time to explain details and answer the many questions of a new hire fresh out of college. Now reporting back to work, I was given a desk in an office shared with Syl Dawson, one of the seasoned HF design engineers. For the first couple weeks, I studied the instruction books on current production HF PAs - and visited with Syl. Soon a desk opened up out in the department "bull pen" and I was moved out there with all the other junior engineers.

The "ISB" Design & Development Project

As the months went by I was assigned a project to redesign the control systems of the 208U-10A 10kW HF PA. This transmitter is automatically tuned with four servo motors. I had to learn servo control theory quickly and was told to go visit with Chuck Anema - the engineering expert on servo tuning. Many months later I had a prototype system designed, built, and working in the lab. The estimated standard cost of my design was $3,300 compared to $15,000 for the system it replaced. My boss, Marv Heidt, had the company photographer shoot the following photo to "sell" my prototype PA control design.



LEFT: An internal promotional photo from the period. We see the components of the older design laid out behind the small enclosure and PCBs of the new design

This caught the attention of engineering management who had been busy planning a secret ground-up design of a completely new family of HF products for ground communications systems. Others besides Dennis Day involved in the extensive planning were Dave Berner, Futures Planning & Program Manager, Jerry Carter, assigned Program Manager after program approval, Ed Rathgeber, Program Manager after HF-80 introduced, Maury Vandewalle, Marketing Manager, and Gary Jost, VP & GM. This was to be a large project, funded by the company, so extensive market research was conducted and detailed business plans as well as engineering design plans were written starting in January 1975. The project was approved by Senior Management and I well remember the engineering kick-off meeting (organized and planned by Dave Berner) led by Dennis Day and Dave Berner that was held on May 1, 1975 in the upstairs conference room of Building 107.

Here was revealed the complete engineering plan containing design requirements, equipment specifications, funding levels, schedules, cost targets, and project assignments. The project was to be kept "Company Private" and was simply referred to as "ISB" which stood for Independent Sideband. The reason for all the secrecy was to accomplish a market coup against our strongest competitor - The RF Communications Division of Harris Corporation. I remember Dave talking at length first how important it was to keep the whole project quiet and secondly the critical design features we needed to achieve in order to be competitive. Some of these early features that I recall were:

HF-80 Design Objectives

Commonality of Subassemblies and Components
Building Block Equipment Components for Flexible System Configurations
Plug-in Cards and Modules for Easy Maintenance and Logistics
Automatic Tuning
Remote Control over Phone Lines
Built-in Test
Recurring Cost Targets
High Performance Technical Specifications
High Reliability
Address the International/Commercial Markets

Dave had a slide that I will always remember (and he used it frequently) as he continually worked to change the cultural mindset of HF engineers in order to make ISB a technical and financial success. It showed a house fly in the center with a large steam roller labeled "Collins" coming to smash the fly from the right. But on the left was a fly swatter labeled "ISB" coming down on the fly. The implication was use a carefully tuned technical and cost effective "Fly Swatter" approach instead of the typical "Make it as good as you possibly can."

Toward the end of the meeting, the engineering assignments were shown. There were to be four design teams lead by four Project Engineers: Syl Dawson, Paul Ziegelbein, Doug Rhodes, and myself. I was the youngest least seasoned of the four and felt honored to be picked. The meeting ended with a room full of "super charged" engineers - all eager to tackle their job assignments. At the risk of leaving out a name, I think it fitting to list the main design team members.

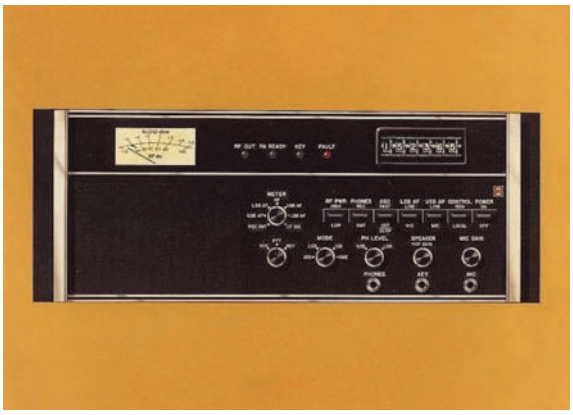
The Receiver, Exciter, and Transceiver
- Sylvan Dawson – Project Engineer
- Bill Sabin – RF translators
- Joe Vanous – Exciter circuits
- Darrell Hennesy – Decade Synthesizer
- Gerry Erickson – Electrical Engineer
- Dave Church – Electrical Engineer
- Keith Wallace – Mechanical Engineer
- Steve Harmening – Lab Technician, Lead

The Remote Controls
- Paul Zieglebein – Project Engineer
- Keith Wallace – Mechanical Engineer
- Gerry Erickson – Electrical Engineer

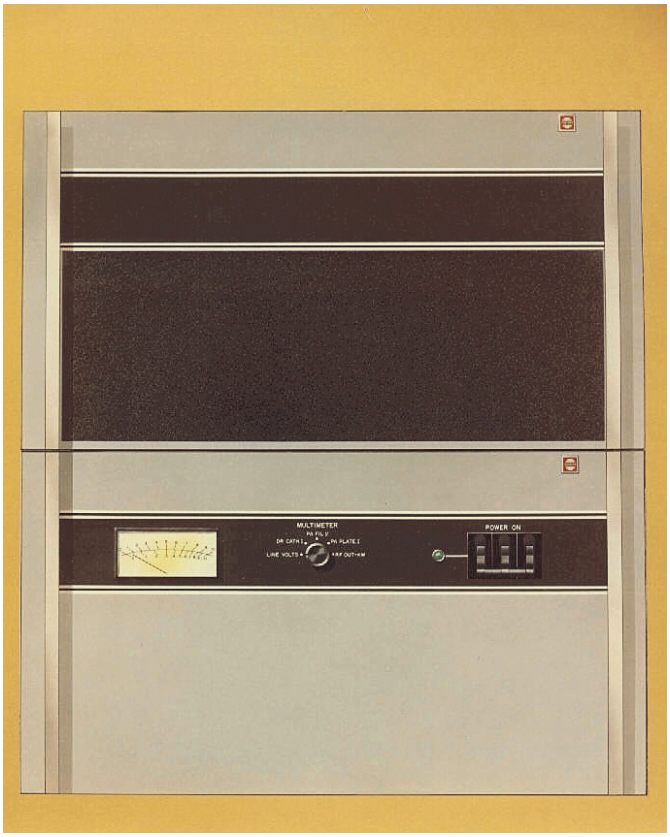
The 1kW Power Amplifier & Power Supply
- Doug Rhodes – Project Engineer
- Wayne Kalinsky – Power Supply Design
- Don Herr – Driver Amplifier Design
- Don Fee – Mechanical Engineer
- Art Roderick – Mechanical Engineer, Servo Drives
- Bill Anderson – PA Lab Technician, Lead
- Tony Wilhelm – PS Lab Technician
- Gene Mick – Lead Draftsman

The 3kW and 10kW Power Amplifiers
- Rod Blocksome – Project Engineer
- Ralph Jensen – Design Engineer
- Ray Beason – Mechanical Engineer
- Art Roderick – Mechanical Engineer, Servo Drives
- Duane "Gus" Gustafson – Lab Technician, Lead
- Bob Smiley – Lead Draftsman

The engineering plans also included artist renderings of what the new equipment should look like. The styling and control layout was carefully designed by our industrial designer and human factors expert Darryl Schultz. The renderings for the transceiver and 1kW PA & PS are shown below. You will notice that we had not yet decided to abandon the "Collins Gray". This would come later when all the equipment was to be painted with textured black epoxy paint



Original rendering for the First Receiver/Exciter



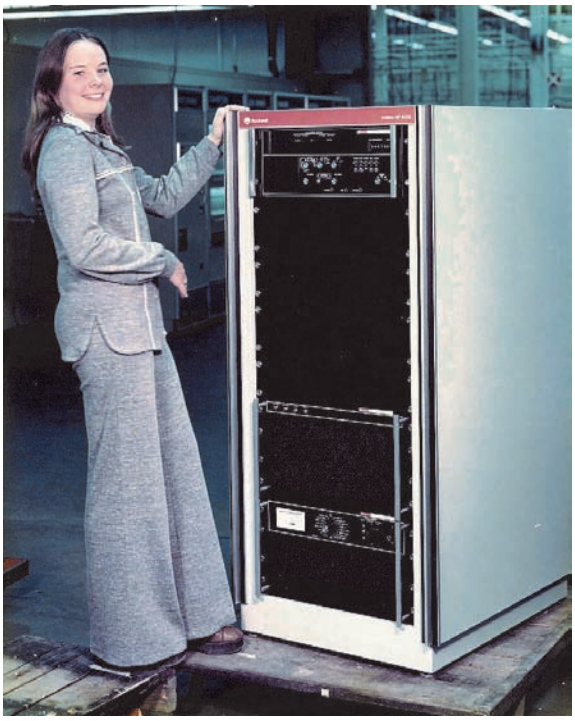
Original rendering of the 1 KW Tube PA in original colors

The design teams worked feverishly throughout 1975 and by early 1976 a few pre-production models were built and tested and we were ready to lift the veil of secrecy and introduce what was now called the "HF-80 Product Line". Dave Berner explained that this equipment was going to carry through the decade of the 1980's. I remember thinking that's a really long time....and still four years away.

Dave invited all the major Collins dealers and subsidiary marketing people to Cedar Rapids for a 4-day conference on HF-80. Each of us project engineers made detailed presentations on our equipment. I remember it as a grand time but we were still feeling the pressure to "iron out remaining bugs" and get the factory production running smoothly.

Dennis Day and the author (right) describing the new HF-80 Product Line to the Collins worldwide marketing team assembled at the Long Branch Convention Center in Cedar Rapids Feb. 9-12, 1976

When the first prototype equipments were completed, our part-time department intern, Nancy Anderson, then a high school senior, posed with the new equipment.



The prototype 1kW system above was shipped to England where it was publically introduced at "Comm '76" in Brighton, England - June 8-11, 1976

The original 10 KW PA Engineering Unit. This photo was taken to advertise the "built-in-test" and maintenance features of the new Power Amplifiers

At the same time the first advertisement (shown on the opposing page) appeared in the AFCEA magazine.

Dennis Day demonstrated the new HF equipment in England, and then shipped it to our subsidiary in Paris, France. The marketing plan was to continually move the demo equipment around the world on a demonstration tour conducted by a member of marketing and engineering. Dennis asked me to do the demos with Bob Hoke (HF marketing) in Paris, France, Rome, Italy, and Bern, Switzerland. In Switzerland, we were to hand it off to two fellows from our subsidiary in England who would take it through three more countries. I remember watching (and missing) the US bi-centennial fourth of July celebrations on French television that summer. But I thoroughly enjoyed the foreign travel, meeting customers and colleagues, and proudly showing off our newly designed HF-80 equipment. I learned a lot and returned home full of ideas for future improvements.

Later in 1977 I was the engineering component for HF-80 demonstrations in Australia, Malaysia, Singapore, Philippines, and Israel - all of whom later bought large HF-80 systems. This first hand contact with our HF customers was valuable experience for me as a design engineer.

Soon orders were coming in, factory production rates ramped upward, and deliveries were made. HF-80 became a huge success. More HF-80 equipment designs were thus funded to provide additional capabilities. The major additions and engineers were:

HF-8040 1kW Antenna Coupler - Glenn Snyder, Project Engineer
HF-8060 Pre/Post-Selector - Walt Roth, Project Engineer
HF-8014/8054 4-Channel ISB - Sylvan Dawson, Project Engineer
851S-1 Receiver - Paul Zieglebein - Project Engineer
HF-8151A (AN/FRT-96) 10kW Transmitter- Rod Blocksome, Proj Eng

Ralph Jensen - Electrical Engineer
"Gus" Gustavson - Lab Tech
Steve Johnson - Lab Tech
Ray Beason – Mechanical Engineer
Art Roderick – Mechanical Engineer, Servo Drives

HF-8023 1kW SS PA & PS - Rod Blocksome, PA EE & Proj Eng

THF-8023 1kW PA & HF-8031 PS Design Team (L to R)

Dennis Juve, PS Draftsman; Keith Wallace, PS ME
Tony Wilhelm, PS Lab Tech; Wayne Kalinski, PS EE
Rod Blocksome, PA EE & Proj. Eng.
Vern Komenda, PA ME; Bill Andersen, PA Lab Tech
Ken Wolleat, PA Draftsman (1978 Photo)

As before, I made many trips abroad with Bob Hoke demonstrating the new solid state HF-80 transmitter. In early 1983 we took two complete systems to Abu Dhabi, UAE. We installed one system in the customers' shabby, dusty, two room concrete building. It had a flat concrete roof which was ideal for a 35-ft whip antenna and the HF-8040 antenna coupler. In a few days we had everything installed and running perfectly and held several "show & tell" sessions with the UAE military. They wanted to keep the equipment for a "few weeks of operational trials". Bob and I went on to Egypt for another customer demo. Three months later they still had our demo equipment when we received a call "stating that our equipment had failed". There was a large order promised, so we quickly dispatched a senior field service engineer to Abu Dhabi. Upon arrival, it was obvious what caused the failure - the building roof over the equipment had collapsed and large chunks of concrete had hit the transmitter. The HF-8031 power supply took a heavy blow to the front panel breaking off most of the circuit breaker handles.

Remarkably, after cleaning up the mess and resetting the circuit breakers with a screwdriver, the equipment came alive and worked! The customer was impressed. I believe this near disaster was at least partially responsible for that order.

HF-80 Production History

Production of HF-80 equipment started in Cedar Rapids, Iowa in 1977. A very few units had come off the production line when a high level decision was made to transfer all HF-80 production to our facility in Toronto, Canada. This decision was driven by facility and labor utilization and not by direct cost analysis.

With this announcement came a collective "groan" from the design engineers as we had just gotten most of the inevitable production start-up problems solved and now we had to go through it all over again with different people in a different facility located an airline trip away.

But the start-up in the Toronto plant was accomplished and the production personnel became experts at assembling, testing, and selling the HF-80 equipment. Many innovative production techniques were introduced to hold costs in line. I remember many trips to the Toronto plant over the years and made many close friends in the process of solving technical problems.

During the mid-1980's HF-80 10kW transmitter production reached an unheard of rate of 1 per day. I remember seeing a delivery semi-truck at the dock unloading the 400 lb. HV transformers and creating a "sea" of these beasts covering the entire dock area. Nearby, the 10kW production line was running like an automobile assembly line. The 10kW PA's mounted on wheeled skids would roll down the line as each assembly operator would install his/her assigned parts. At the end of the line would emerge a completed PA to be taken over to a cage for final testing and a 48-hour "burn-in". It was a memorable sight I'll never forget.

One large HF-80 customer was the US Air Force who modernized their global HF Ground Station network with HF-80 10kW transmitters and receivers. It was always a source of personal satisfaction to visit one of their transmitter sites and see the long rows of the PA's I had designed years earlier. An example shown below is only a small portion of the HF-8022 10kW PA's installed at the USAF Davis, California site.

Another large HF-80 order came from the US Navy. They completed a procurement for 475 10kW transmitters. They had to be "transmitters" and not separate exciter and PA boxes. Plus, there were several other requirements not part of our standard HF-80 product line. This was a huge potential order and competition was stiff. The Navy procurement process included submitting your "candidate" equipment to be subjected to a series of tests in a formal Technical Evaluation. There were strict rules on how the Tech Eval was conducted. We quickly designed and built a prototype HF-8151 10kW transmitter and delivered it into the Tech Eval - while at the same

USAF Davis, California HF-8022 10kW PAs in service

time bidding and writing the proposal. Three other companies did the same: Harris, Marconi, and Continental. It was a very intense time.

Per the Tech Eval rules, if a company's product suffered a failure or failed a test, the company would be notified and had 72 hours to respond and fix it. I remember getting such a call during our 4-day holiday for Independence Day. I caught the first plane out to Norfolk, Virginia and in the course of trouble-shooting our problem found a resistor out of tolerance. I went to Radio Shack, bought the proper resistor, and had the transmitter going again the next day. We went on to eventually win the contract with very few people knowing our Tech Eval radio contained a Radio Shack resistor.

The next technical hurdle after winning the Navy contract, was to successfully pass an Operational Evaluation. This would clear the way for "full rate production" of 475 transmitters. Op Eval was to be conducted with eight production transmitters to be installed at the Navy site near Morón de la Frontera, Spain. The Navy procurement folks were just as keen to expeditiously pass this test as we were. Op Eval covers all aspects of introducing a new system into the Navy: Technical performance, Logistics, Maintenance, Operations, Training, Instruction Books, etc. I spent several weeks in Spain preparing for Op Eval. The first task was to check and certify that all eight transmitters were properly installed and operating up to spec. Second was to provide on-site training to the Navy operators and maintenance personnel as their performance with the new equipment was critical.

Training the operators went smoothly as it was easy to learn and not very complicated. However the maintenance folks were a different story. The first day I gave them an 8-hour lecture on the theory behind every circuit in the transmitter. It was a boring, hard-to-stay-awake session for the young troops. That night I decided to try something different. The following morning I announced we were going to divide the class into two teams. They could go have a coffee break while I would introduce a fault into two of the transmitters. Each team got a transmitter and I would measure how long each took to: a) identify the fault and b) repair the fault and then demonstrate the transmitter operating correctly. We would do this exercise repeatedly with progressively more difficult faults. I would keep score and award a prize to the winning team at the end. This got their attention in a big way.

However, the Navy procurement engineers from Norfolk expressed concern that they might damage a transmitter, requiring parts to be shipped in from Cedar Rapids, and thus delay the start of Op Eval. I was worried about this possibility as well, but thought the benefits outweighed the risk. Over the next week the competition was a success - even spurring several trainees to take the books home at night to study. At the end while driving back to the hotel outside Seville, the Navy engineer constructed a home-made award. That night at dinner he presented me with the "Seat of your Pants Engineering Award". It is one of my most prized mementos from this time period.

Three months later we were notified that we had passed Op Eval - something that rarely happens on the first attempt.

During the 1980's limited HF-80 production took place in two other locations - Melbourne, Australia and Belgrade, Yugoslavia. We landed a large contract with the Australian government that included a requirement for in-country content. Our subsidiary in Melbourne geared up to assemble the HF-8022 10kW transmitters using components purchased from our qualified venders and shipped from the US to Australia. But shipping the heavy transformers was going to cost as much, or more, than the transformer. The solution was to qualify new transformer venders in Australia - which we did after a couple trips to Australia.

Yugoslavia was keen to buy and produce a large quantity of HF-80 equipment and, after a long series of trips back and forth and tedious negotiations, contracts were finally signed. I remember a celebration dinner at the Cedar Rapids Country Club with our marketing hosting five customers from Belgrade. Prior to dinner, our marketing manager, with much fanfare, produced a bottle of Yugoslavian liquor and expounded on his difficulties in finding this special liquor in Iowa. A toast was made with everyone standing in a circle. It reminded me of paint thinner. The Yugoslavian engineer standing next to me whispered "Don't tell anyone, but in Yugoslavia this is a special drink used only at wedding ceremonies" Of course, afterwards I did tell, and we had a big laugh.

The Yugoslavian HF-80 program initially involved the outright sale of HF-80 equipment followed by a gradual ramping up of a licensed production facility named Pionir and located just outside Belgrade. This process was drawn out over a period of several years.

By 1990 the world was changing. The Berlin Wall came down and the Cold War ended. Orders for HF-80 equipment declined and the decision was made to close the Toronto plant and sell the land and buildings. It was a sad time - particularly for the dedicated personnel in the plant. In the next couple years there were occasional attempts to revive HF-80 production back in Cedar Rapids but all fizzled for various reasons.

Looking back over this 15 year reign of HF-80, I'm amazed at the amount of worldwide sales and the variety of systems produced. The HF-80 success was due, first of all, to the experienced and skilled leadership at Collins and to the dedicated design and development teams backed by the skilled Collins support functions. I was fortunate and privileged to have been a part of it all.

de Rod Blocksome, K0DAS

Editors Note: Rod is retired from Rockwell Collins and is also the past curator of the Rockwell Collins Museum in Cedar Rapids. He writes for the *Signal Magazine* often and is passionate about preserving the history of his company, its people and its equipment.

The Pat Fox Story

From the pages of the Cedar Rapids Gazette, October 27, 2013

> *"Patricia "Pat" Jeanne (Colton) Fox, born Oct. 23, 1946, passed away at St. Luke's Hospice, Cedar Rapids, on Oct. 26, 2013, after a very short battle with cancer. Services 10:30 a.m. Wednesday at Morgan Funeral Choices, Mount Vernon, by Celebrant Mary Morgan. The family will greet friends from 5 until 7 p.m. Tuesday at the funeral home. Burial: Rose Hill Cemetery, Mechanicsville.*
>
> *Pat worked at Rockwell Collins for 45 years, retiring in 2011. While there, she took every test she could to advance her employment opportunities and served as IBEW Union Steward. She was a volunteer at Treasures/ Bridgehaven and WRAP (Wheelchair Ramp Accessibility Program). Pat was also a member of The Red Hat Society."*

I encountered Pat Fox a number of months ago while I was on a trip to Cedar Rapids to do some research for an article. She was a person that made a quick impression - very active and quick to smile… and definitely a woman of her own mind. I liked her right away. Short and wiry…. the Spanish descriptive word "pistolero" wants to come to my lips.

We met at a retirement group lunch meeting. She had worked in production at Collins Radio for some 45 years, went on to drive a delivery truck on Collins campus business and retired finally in 2011. For her personal transportation, she also chose a pickup truck.

She told me a story that still makes me laugh, is typical of her I think, and also sheds some light on Collins management.

When she went to work for Collins in 1966, and after some initial training, she was put on the line "on probation" for six weeks. This was customary then. On her very first day, and nervous about her performance, she was working at her assigned task when she felt the presence of someone standing behind her. She turned to find her foreman, accompanied by a man in a lab coat. They were peering over her shoulder and watching her work. She quickly turned back to her work and continued. But….she could feel those eyes watching her. She turned again, only to find the man in the lab coat even closer and leaning in studying her work.

Again she looked back to her job – now feeling even more self-conscious. Finally, not able to stand the stress, she turn to Mr. Lab Coat, and in the presence of her foreman, announced: "Get the Hell out of here. I am on probation and you are making me very nervous."

Well, Mr. Lab Coat made a short apology and hustled his coat right out of there. After they had left, Pat returned to her work. Later in the day, at her break, the foreman walked over to her and commented: "You know that man that you told to leave? Well, that was Arthur Collins !" Now fearing for her job, she was then told that Mr. Collins had actually appreciated the fact that he was asked to leave so she could do a better job without being watched.

Like I said…..Pistolero!

Pat Fox passed away on October 26th of this year after a short bout with cancer. She was 67 years young. We have lost another fine Collins employee.

Bill Carns

Printed with Pat's prior permission from an earlier interview.

Did You Know?

Most of the readers of this *Signal Magazine* are members of the Amateur Radio community. We, and almost everyone else, all know the stories of young Art and his ham radio exploits. We know how he built his own first equipment - and we know how he helped make the MacMillan, and then the Byrd, expeditions the successes that they were by supplying communication support in one form or another.

Few know though that Art Collins was not a ham…..Ready to argue? ….. Read on.

We do know that Art Collins was first licensed as 9CXX as a young man of 14 in 1923. Later, in 1937, when the prefix call signs were adopted, Art became W9CXX. So….What am I talking about?

Let's fast forward to 1941. Arthur is up to his neck in new developments, engineering work, and the expansion of his new company. Just around the corner, the war is looming, and Art knows this well enough. In the Q1 2013 issue of this magazine, we all read about the preparation and foresight that ruled at Collins during these years before the war officially started. There was little time for ham radio at Collins.

Sometime during 1941 – we do not know the exact date – Art Collins let his (then) W9CXX license expire. Art Collins, boy wonder, founder of the premier ham radio equipment supplier in the world, wasn't a ham.

Times at Collins did not get any more relaxed for many years. Art and his company continued to prepare for, then support, the war effort and grow the company. Then, after the war, the company and Art had a whole new set of challenges.

During the late 40s, amateur radio continued to evolve at Collins – The 30K, the 32V and 75A series were added to the catalog. However, at the same time (you will remember from the last issue) financial recovery from the loss of business after the war continued to be a pressing issue with the management of Collins Radio. It was not until 1949 that sales and financial performance started to turn around.

So, let's look at early 1949. The backlog is up significantly for the first time since the war's end. Things are feeling a little better to Mr. Collins. Noteworthy also is the fact that in January of 1949 John Foster had just started work on that beautiful KW-1.

Art renewed his ham license sometime mid-year in 1949. He was again a ham. But, there is another facet of interest to this story.

In 1949, there was no vanity call-sign program. When you became a licensed ham, you received the next call sign that came up on the unassigned list. Let's ignore the fact that 8 years had passed since Art lost his call. What is relevant is that sometime during that 8 years, one William Kennedy living in Chicago had been assigned W9CXX. Art's call sign was gone. It was too late to renew it anyway. In addition the call sign boundaries now placed Cedar Rapids Iowa in "zero" land. And, call sign boundaries meant something in those days.

Now we get a little peek at Art's influence and the connections that Art had in our government. We also get a peek at what those government folks thought of his contributions to the war efforts and communication technology.

Mysteriously, Art is issued W0CXX. And, that is the rest of the story. Art could now use "CXX" with that beautiful KW-1 that was soon to be introduced.

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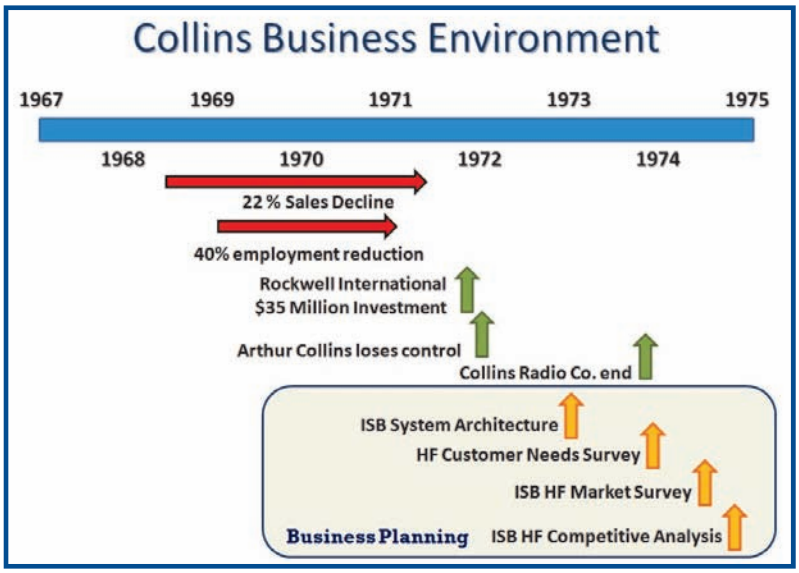
HF-80 . . . . From Concept to Market

by Dave Berner, Retired Rockwell Collins

When I was asked to share how the HF-80 Product Line was conceived, I had to reflect not only on the Collins business environment, but also on my work experiences leading up to the HF-80 "hatching". Upon graduation with a BSEE I had been offered a position with Collins in 1962. Early assignments were developing technical manuals for a new HF Product Line called Universal Radio Group. It wasn't long after that I was then assigned to develop detailed test procedures for the Apollo HF Transceiver. Wow! What a privilege. Following that assignment, I was transferred to the Surface Communications Product Line organization. Here I became involved with developing customer proposals, marketing literature, and customer marketing support.

During this period the Univ. of Iowa was offering night extension MBA courses in Cedar Rapids. I was accepted into the program and began with studies in finance and marketing. This track was interrupted when I was transferred to Texas but provided valuable insight that became helpful as time passed.

As part of the company's growth, in 1967 management moved our product management group to the Richardson, Texas facility along with product systems production. This was about the same time that the company started marketing C-System HF (URG II) and our group was assigned management responsibility for the newly developed URG II product line. Development and production of the functional "slices" was disbursed between Cedar Rapids, Iowa and Richardson, Texas.



In the fall of 1970, several in our group were asked to transfer back to Cedar Rapids along with the Surface Communications Product Line responsibilities. This was in the midst of the decline in business and lack of profitability. My direct responsibilities related to URG I and URG II as Product Line Manager.

That being said, the environment in which we were operating in the late 1960's and early 1970's would influence future business success or failure. This environment set the stage for the future of the company across all of its businesses. Success would be determined by how the environment would be recognized and how we would react in the new culture to yield profitable competitive success.

Collins Business Environment Transition

All product development activity during the late 1960's and early 1970's was influenced by the direction of Arthur Collins and his C-System vision. In his book *Arthur Collins Radio Wizard,* Ben Stearns captured recollections of Bob Cattoi (Head of engineering management and development of computer projects). Art said: 'Let's start with what we are really trying to do --- that's to manage information. To manage it we have to compute it, control it and make some decisions. We have to have more than just a computer, more than just communication --- we have to look at the way information is formatted, the way we use communication and computers.' He talked about the importance of the data base. He talked about what he called data architecture, overlaid on control architecture, overlaid on communications architecture. It was this forward thinking concept that became known as the Collins C-System. This broad vision would require thousands of engineering development hours and related infrastructure costs. As development progressed over many years, research and development resources from ongoing business was insufficient to underwrite the ongoing C-System development. Declines in profit from ongoing core businesses followed significant declines in orders and sales due to market shrinkage (recession) and competitive encroachment in traditional markets. Communications equipment demands for the Vietnam conflict and the manned space program were good business contributors but were not sustainable. Commercial avionics businesses tied to cyclical airframe market demands and emerging competition were also a factor impacting bottom line cash flow. External bank financing was not enough to sustain the C-System appetite for development funds. In addition, funds for development of existing product improvements and/or replacement dried up.

After employment reductions of 40 percent during fiscal 1969 through 1971 and exploration of outside financing, on August 31, 1971, Collins shareholders approved revised Articles of Incorporation. The revisions included increasing the size of the Board of Directors from 12 to 13 members and issuing new convertible stock. On September 2, 1971, North American Rockwell made an investment of $35 million in Collins in return for newly issued stock, and elected seven members to the board. Arthur Collins remained president and CEO until November 23, 1971 when he was asked to relinquish his position and offered a technical advisory position. Robert C. Wilson was named as president and CEO and began the changes to Collins' business model. On November 2, 1973, Collins Radio became part of Rockwell International in a merger that raised another round of cash.

As one reflects back today, some forty years later, Arthur's visions were futuristic and ahead of the technology it would take to cost effectively implement the concepts. As he foresaw, the use of digital communications, computation, and control technologies continue to expand and impact mankind.

Electronic Technology Advances

During the period of Collins Financial turmoil in the early 1970's, there were several significant technology advances external to the company that would prove to have an impact on Collins business and in particular Collins HF communications business.

The development, launch and network integration of geostationary satellites brought the reality of near instantaneous long haul communications. This giant shift in communication strategy was related to a number of underlying advancements.

- The development of large scale integrated circuits and related manufacturing processes
- The development of integrated computer control of HF Systems
- The development of the first microprocessor
- The development of higher power rf semiconductors
- The development of multilayer printed circuit boards and related manufacturing processes

Expansion of Collins HF Core Competency

From his boyhood interest in radio, followed by building a company initially producing high-frequency radio equipment, Arthur Collins established a reputation for superior performance, high quality, and reliable communications equipment. Expansion into aviation equipment followed a natural progression of utilization of the rf spectrum to serve mankind. Over the years the company's offerings covered not only the amateur radio market but also aviation, telecommunications, and commercial broadcast for domestic and international customers. The following paragraphs focus on a segment of the overall business that addresses high-frequency communications for primarily fixed station and transportable application. It sets the stage for the conceptualization, planning, and development for what has become known as the HF-80 Product Line.

Collins HF Fixed and Transportable Systems Equipment

Universal Radio Group HF Products --- URG-I

Ongoing orders and sales of URG I equipment and systems since their introduction in 1962 were generally split between international (40%) and US Government (60%) customers. Peak order volumes achieved in 1967 declined by the early 1970's. This was partly due to reductions in US Government spending following the Vietnam Conflict and price pressures resulting from the availability of more current competitive technologies. By the early '70s, there were more than 15 domestic and international producers of various kinds of HF communications equipment.

C-System Design Driven HF Products --- URG-II

A small part of the overall conceptual C-System architecture and development effort included a new family of HF equipment. *Computer control interface* was a dominant technical feature along with high performance Mil-Std 1553 Link 11 data compatibility characteristics. The C-System Products mechanical packaging (at that time) retained the Aeronautical Radio ATR packaging concept with next generation multilayer circuit boards interconnected with multilayer back planes.

In an April 1, 1967 memo to "All Marketing Personnel" John Boyle, marketing vice-president, stated…

> *A basic feature of Collins' new CCCS oriented HF product line is the multiple use of various slices in all HF application, including surface, aviation, marine, etc. Traditionally we have operated largely on the basis of specific product to specific applications. This was practical and desirable in the past, as black boxes were generally designed to meet specific application requirements. We are now in an enviable position of having considerable flexibility to meeting various applications by use of common slices.*

URG II high speed data performance for the state-of-the-art was excellent and product slice configurations were initially accepted by the US Air Force. Orders during the first five years prior to 1973 were 95 % US Government on a handful of programs. These products generally served the high end market (technical performance & packaging design) and there was price limited international market penetration and related total business volume.

Figure 2 - URG I HF Product Line System

HF Fixed and Transportable Market Environment

US Government HF Equipment and Systems

As the United States ramped up its military involvement in the Vietnam War in the early 1960's, several major HF communications programs were initiated by various branches of the US military. During this same period of time, the United States was also involved in the "race to the moon" Both of these major US Government expenditures provided a strong technology business base in the country and at Collins Radio.

One might ask what role HF communications played in Apollo missions. On somewhat a parallel track, the run up to the moon landing was also the development of satellite communications. During this time, HF systems (URG I) were installed at tracking stations around the globe. An HF suite of equipment (URG I) was installed aboard the Apollo Range Instrumented Aircraft. The Apollo Ships (naval tacking and recovery fleet) had an HF suite (URG I) aboard. And, the Apollo Command Module also had a fixed frequency transceiver on board for recovery operations.

International HF Equipment and Systems

HF communications was still the mainstay for long haul communications circuits for aviation, shipboard, and telephone circuits. Traditional customers besides international military organizations included post and telegraph services as well as industrial applications. Addressing this market were several European HF manufacturers as well as US.

Collins HF Competitive Positioning

In the beginning, Collins Radio technology was rooted in high-frequency Amateur Radio by 9CXX, young Arthur Collins. Equipment produced by the company became the equipment of choice by professional and amateur operators alike. Arthur also had an intense interest in aviation and saw the need for aviation related communication and electronics. His amateur radio hobby and aviation interest were key drivers in the development of Collins Radio business from incorporation in 1933 forward.

In the '40s, aviation electronics began to be packaged in a series of standard "black boxes". The new standard that evolved defined maximum height and increments of depth and width to accommodate the particular electronics contained. This packaging and racking standard was referred to as ATR.

By the mid-1950's, Collins had established itself as a technologically superior, high quality and reliable manufacturer of aviation electronics. The company was a dominant supplier of avionics for commercial and government transport aircraft. This included communications, navigation and flight control products and systems. In parallel, amateur, fixed station, transportable and shipboard board H-F equipment markets continued to grow with advances in Collins products.

During the early 1960's, Collins developed an HF family of ATR packaged I-F and R-F Translators, preselectors, 1 KW power amplifier, power supply, and FSK controls. This family was called, Universal Radio Group. It provided coverage of the 2.0 to 30.0 MHz frequency spectrum. The packaging was ideal for large aircraft installations. For ground applications, a system of shelving, cooling air, electrical interconnects of the selected ATR boxes had to be constructed. A series of standard shelving and racking products was developed in the mid 1960's to minimize unique systems integration expense.

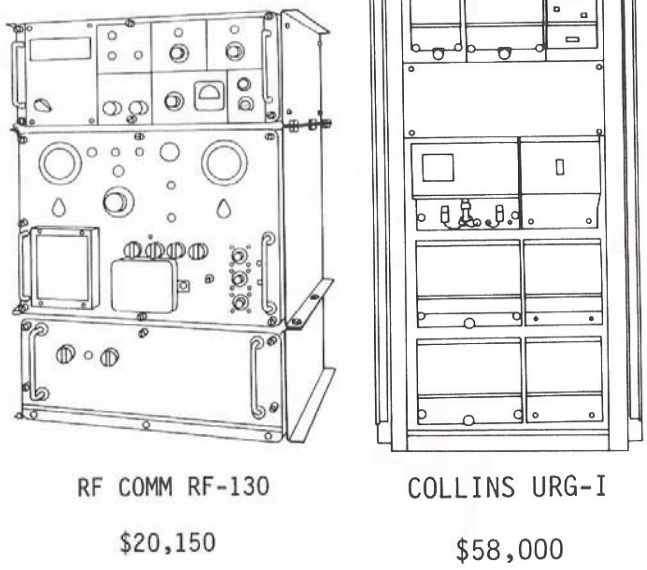
In the 1950's, two engineers left Collins Radio to join General Dynamics and subsequently became acquainted with Bill Stolze. Bill had worked for RCA, Stromberg Carlson, and P.R. Mallory Co. in various engineering positions. The three of them decided to start a new radio communications company in Rochester, NY. Bill's stated philosophy was…"There is a place in the world for a company specializing in radio

communications." In 1961, RF Communications, Inc. was established. By 1969, when Harris Corp. acquired RF Comm, their sales had reached $26 million with a mix of US Government and international business. When Collins marketing representatives were asked who their primary competition for HF ground and maritime products was …. the answer was more often than not, RF Comm.

URG I versus RF Comm

Since the RF Communications company was a start-up by two former Collins engineers, one can assume that the insights into Collins technologies and strategies were competitively useful to them. During the late 60s, a period of that corresponded with the financial turmoil at Collins, RF Comm had established itself in the Fixed Station and Transportable HF market segments. There was a wide spread between RF Comm (much less expensive) and Collins in prices offered for comparable performance 1 KW Transceivers. It didn't take a rocket scientist to make a purchase decision given that either offering would meet their performance requirements. The accompany figures illustrates the 1 KW physical and cost comparisons. The Collins 10 KW Transceiver was also priced at 26% higher than the comparable RF Comm offering.

Figure 3 - RF Comm & Collins 1 KW Transceivers



Although there were other domestic and international producers of HF equipment addressing various niche markets at the time, we chose RF Comm as the "team to beat".

URG II High Performance HF

Given that URG II addressed more sophisticated performance applications and its cost was appreciably more than comparable URG I offerings, there was little fit for URG II in the higher unit volume HF market segments of the day. Thus, URG II was not a competitive player in the Collins versus RF Comm arena.

Collins Business Transition --- Enter Rockwell

Business Restructuring

When Robert Wilson began work as President and CEO, the company was organized functionally with principally a top down management structure. A major reorganization took place in 1972. The functional organization was broken apart into a decentralized structure made up of a number of profit- and loss-responsible, market-oriented divisions. The new organization enabled personnel throughout the Company to initiate and carry out appropriate actions.

Shifting Business Operations Discipline

The designated business profit centers were directed to develop strategic plans with particular emphasis on technology leadership. Operating financial goals were set and progress was reviewed monthly. Quality standards were to be maintained, and added emphasis was given to customer service. The initial $35 million North American Rockwell investment was put to immediate use to help stem the flow of red ink.

Limited Discretionary Development Funding

In the years prior to Rockwell, discretionary R&D funding was directed primarily to C-System related engineering projects guided by Arthur Collins. Due to the financial turmoil in the early 1970's, discretionary R&D funds were significantly limited to a few market related project commitments. Business strategies embraced customer sponsored development programs which were primarily related to US Government programs. Very little funds were directed towards in house engineering "ideas". However, as overall operating revenue improved more discretionary funds became available.

Something Must Be Done --- URG Business Decisions

The URG I ATR packaging and design concept enabled functional configuration of modules within the black boxes as well as flexible combination of boxes. This feature allowed custom adaptation of the various modules and units to customer requirements. However, production inventory planning and throughput was administratively complex, costly, and hurt customer "order to delivery" cycle times. To simplify administration, reduce costs, and improve delivery times, standardized configurations were defined and placed into production. This was known internally as the Standard URG (SURG) project.

URG I products were already in production when I was appointed the Product Line Manager in July of 1967. Responsibility for the URG II Product Line was added in July of 1969. The previous paragraphs have outlined the environment the company was operating during this period, as well as the management changes that then took place in 1972. Management restructuring into market/business focused profit centers provided an opportunity for strategic thinking and an environment for market driven business planning. In addition to day to day business activity, we had the opportunity to address the future and look for ways to profitably grow the business.

Having been involved in many competitive procurement activities in both domestic and international markets, I had experienced winning - and losing! - contracts for URG equipment and systems. Something needed to be done to improve our competitive position and expand our addressed market especially where potential market growth was indicated. Independently, I developed architecture for a new product line that would replace URG I. The new Product Line would include a new family of Receivers, Exciters, Transceivers, 1 KW Linear Amplifiers, and value engineered 3 KW and 10 KW Linear Amplifiers. The concept was laid out on a single 36" x 33" piece of Clearprint paper dated 1/23/73.

International customers were procuring this type of equipment as off the shelf catalog items from competition. RF Comm also had their equipment listed on the GSA catalog for "off the shelf" delivery. Given that this was a time of discretionary austerity and that there was no single outside customer program to provide development funds, it looked like it would be an uphill battle to obtain internal funding to move forward.

In March, 1973, Collins marketing & international dealers were surveyed relative to the need for a 1 KW Power Amplifier. The data was returned and compiled in August, 1973. In a sense, it raised more questions than it answered. What did the customer really need for long haul comm? The power amplifier was just a piece of the puzzle.

In May of 1973 I transferred to HF Engineering in the staff role of HF Applications Engineer. This included department planning activities in support of the department manager, Dennis Day. My horizon was widened to include all HF related markets and business. Meanwhile URG Product Line business was not getting any better. In October, 1973 I led the development of a Customer Needs Survey for HF SSB Equipment. The survey format addressed Market Potential Evaluation, Competitive Evaluation, Product Definition, and a price-demand analysis. Inputs were compiled by December, 1973. The conclusions were…

- The lower cost HF Market was real - especially internationally
- Complete package subsystems were desirable
- Separate receivers and transmitters were required
- Independent Sideband (ISB) operation was required
- A simple remote control was required

Based on the survey inputs and incorporating the conceptual architecture (adjusting where necessary), Company Private Product Definitions were developed for what was to become the ISB (Independent Sideband) Product Line. In March, 1974, this information was shared on a confidential basis with relevant marketing personnel. The market potential and competitive evaluation data was once again sought on the basis of the specific Product Definitions…. Were we on the right

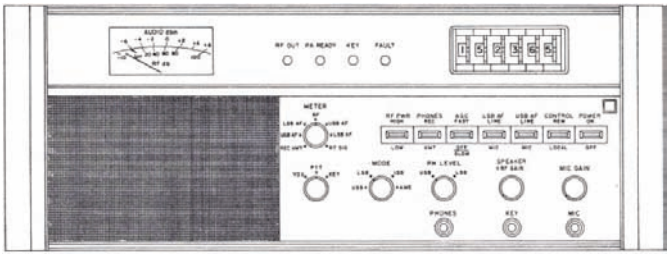


Figure 4 - ISB Receiver/Exciter Concept Rendering

track for success? …. Data was returned and compiled in July of 1974. Meanwhile, overall, the business climate was significantly improving. Rockwell International (North American Rockwell renamed in early 1973) now included the "Radio Company" and just maybe we could obtain some "Company" sponsored research and development funds. However, we needed a comprehensive Business Plan. In May, 1974 I was appointed to the position of HF Futures Planning within the HF Engineering Department. This enabled me to focus more effort on the ISB Project. By September, 1974 the process of developing a business plan for ISB HF was initiated. The overall Business Plan included related plans for Marketing, Product Design, Manufacturing, Product Support, and Finance. I had the task of coordinating the effort and pulling together and organizing (and documenting) the final Business Plan. This effort was completed on April 15, 1975.

The ISB Business Plan

It had been a little over 27 months since I had laid out the initial concept for the URG I replacement product line. As noted previously, this was a time of significant change for Collins Radio. Company sponsored development related to the C-System drained financial resources. US Government business declined following the Vietnam War and NASA's development of the Apollo program. Competitive positions of existing products were marginalized. All of these factors minimized the availability of company sponsored development funds for existing product improvements. Thousands of employees were laid off and there was a period where employee salaries were cut across the board.

In addition to the $35,000,000 infusion of capital funds, Rockwell brought business discipline to the forefront of operations and management structure. Internal business related training, facilitated by outside resources, was put in place. These were the years of bottoming out and turn around in the business fortunes of the company. We were hopeful.

The surveys completed by front line marketing and dealer personnel, coupled with available market data, provided a basis for the business plan. The market was real especially in the international community. This would be our primary focus. The following excerpts from the Business Plan provided the direction.

Key Objective

Profitably regain market share lost to competition, increase the addressed market, and reestablish Collins as the leading supplier in the fixed station/ transportable HF ISB international market within five years.

Success Strategies - We would:

* Offer only those products that can win in the competitive market place by optimizing cost-effective design
* Develop a business plan which allows operational flexibility to achieve the business objective within the competitive arena
* Establish a leadership position in cost effectiveness, technology, marketing effectiveness, and product support
* Minimize cost and conserve cash by drawing on existing company resources
* Establish a commercial position through the international marketplace
* Obtain supplemental customer development funding for product line enhancements
* Obtain additional competitive leverage by employing multinational production
* Establish effective program management procedures

Competitive Design Strategies

* Technical performance to be compatible with ITU/CCIR international recommendations
* EIA standard 19-inch rack mounting
* "Works-in-a-drawer" modular serviceability
* Built-in audio and control elements
* Unique sensory features
* Plug-in control options for local, remote and computer control

Low-Cost Design Strategies

* Utilize best applicable features of existing designs
* Minimal design to achieve necessary technical performance using commercial parts
* Employ design-to-cost and value engineering techniques
* Maximize commonality of parts and modules

Marketing Strategies

* Establish a dedicated marketing team to effectively introduce the product line
* Initial sales emphasis on international marketplace to establish a commercial position.
* Continually monitor and update marketing plan to reflect market trends.
* Develop comprehensive sales and advertising tools.
* Conduct an in-depth international sales seminar to ensure maximum enthusiasm and familiarity prior to introduction.
* Encourage live equipment demonstrations and evaluations with key customers.
* Produce ISB hardware on a planned speculative release basis to provide competitive availability.

Product Support Strategies

* Equipment maintenance concept to be established concurrent with each unit design.
* Commercial maintenance manuals prepared for "on-site" modular replacement and service center part replacement.
* Training programs including video instruction will be produced.
* Standard test equipment will be emphasized. Special test equipment would be minimized.
* Computer program to provide customized recommendations for customer spares.
* In place international service centers will be enlisted to support products.
* A full time ISB Trained field service engineer will be engaged.

ISB Equipment will be warranted for one year.

Financial Objectives

The financial plan called for an upfront company cash commitment of $800 thousand during fiscal years 1975 and 1976. Projected orders for the five year period following market introduction were forecasted as $ 53 million. Anticipated profit before taxes was greater than 25%. Among other things, this would be dependent on achieving a competitive commercial pricing position in the marketplace.

Management Presentation of Business Plan

A management presentation was assembled, and scheduled. Yours truly was given the opportunity to stand up and pitch the plan on behalf of the HF Product Business Area. Overall, I felt good about the presentation and was able to answer questions. Support of the HF Business Area personnel present was positive. A senior marketing manager stated that he was of the opinion, that in view of the emerging satellite communications technology, HF was dead. Is this really a good investment? Discussion ensued.

Management Approval is Granted

The ISB Business Plan was completed on April 15, 1975 and signed off by Gary Jost, HF Programs Manager the following day. Subsequent requests for engineering expenditures were submitted to company management. Following review and 16 signatures later, including the Rockwell Group President Don Beall, the approval memo was received by the team. ***We were good to go***.

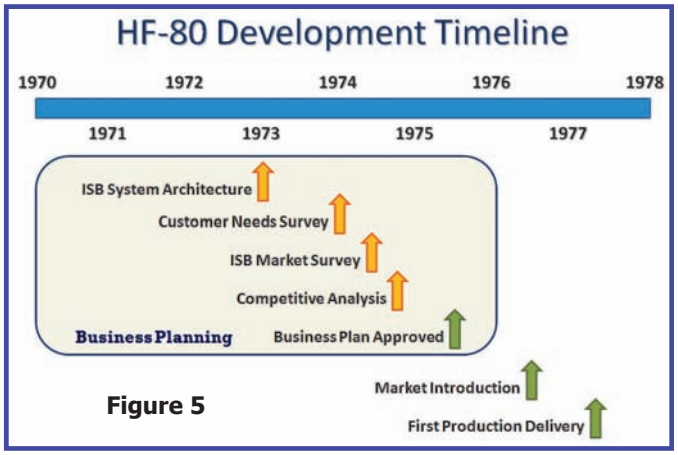


Figure 5

ISB (HF-80) Product Development

It was twenty-seven months from initial inception to business plan approval. A deliberate process of internal education and external research and surveys (slowed somewhat by lack of resources during periods of company financial stress) finally resulted in an actionable plan. The challenge now before the development team was to convert paper and thoughts to hardware in 12 months. Market introduction was scheduled to coincide with a major international trade show scheduled for June, 1976. Figure 5 shows the total timeline.

Development Team

Key players assigned to the development team were also involved in the formulation of the business plan. A broad base of experience in HF equipment and system design and production was available in those selected. In addition, there were several other personnel from various disciplines involved on an *as needed* basis throughout the development, testing, and production integration phases. In addition to myself as the Program Development Leader, the initial team consisted of the following assignments: Receiver/Exciter Project Engineer: Syl Dawson, Remote Controls Project Engineer: Paul Ziegelbein, 1 KW Power Amplifier Project Engineer: Doug Rodes, 3 and 10 KW Power Amplifiers Project Engineer: Rod Blocksome, Overall Mechanical Engineering Lead: Chuck Gregory

Commonality, Commonality, Commonality

The culture of the Collins Radio Co. prior to the Rockwell investment, was that of advancing the communications technology state-of-the-art. High quality design practices to achieve reliable performance in environmental extremes were the norm. Cost of the hardware was often overlooked in favor of these practices and objectives. The advent of the Rockwell investment provided an opportunity and impetus to shift the culture to a more balance approach to planning & design. Competitive cost effectiveness with competitive technology became the turnaround mantra.

One of the key design strategies emphasized for the ISB program was that of commonality. Commonality of commercial components, throughout the product line, would maximize composite production purchase quantities and reduce costs. Commonality of modules across the individual products within the product line to minimize production costs. Commonality of mechanical parts across the product line was also sought. This would also include considering placing added holes in chassis castings and fabricated panels if they could be used in several places without hampering design integrity. This would reduce production set-up costs and amortize those set-up costs over a much larger production quantity. This approach to the design was also reinforced by challenging "design-to-cost" targets.

HF-80 Is Born

During the planning and development process the new competitive product line carried the internal identification of the ISB Program. The market product nomenclature was planned to complement an overall marketing campaign. Traditionally, new Collins products were given the "next in line" type number nomenclature for respective equipment types. The "keeper of the type numbers" released the type numbers to the product designer and maintained the records for the company.

The marketing strategy for product identification for the ISB Program was to provide a means to achieve the following….

Market recognition of a family of products
(EG. URG, S-Line, Micro-Line, etc.)
Brand image identification with function
(EG. Elmer's Glue, Scotch Tape, etc.)
Provide a purchase motivation facet
(EG. Satisfies current and future needs.)
Establish relationship with Collins quality
(New generation of proven products.)
Provide for functional identification
(XYZ where X=function, Y=model, and Z=option)
Individual product identity with the product line

The underlying theme of the program resulted in **a family of HF products incorporating *technology for the 1980's, available in the 1970's, at prices of the 1960's*….. HF-80.**

Figure 6 – Early HF-80 System Components Including the HF-8020 1 KW PA and 8030 P.S. And the HF-8070 Receiver/Exciter (Left)

HF-80 Product Family

The HF-80 product family included a receiver, a receiver/exciter, exciter, 1,000 watt power amplifier, 3,000 watt power amplifier, 10,000 watt power amplifier and system remote control units. Equipment type number identification was assigned as follows:

HF-8010 Exciter	HF-8090 Xmtr Remote Control
HF-8050 Rcvr	HF-8091 Rcvr Remote Control
HF-8070 Rcvr/Exciter	HF-8092 Xcvr Remote Control
HF-8020 1 KW P. A.	HF-8030 P. A. Power Supply
HF-8021 3 KW P. A.	
HF-8022 10 KW P. A.	

HF-80 Market Introduction

Bringing Marketing Up To Speed: Prior to its formal market introduction, Collins international marketing staff and dealer organizations were invited to Cedar Rapids for a comprehensive seminar on February 9-12, 1976. Overview marketing presentations and in depth technical presentations were made by the development program team. It was once again an opportunity for input to the development team as

Figure 7– The HF-80 Marketing Introduction meeting held at the Long Branch in Cedar Rapids February of 1976

well as responding to questions from front line field personnel.

HF-80 Advertising for trade periodicals, press releases, marketing literature, and slide presentations were produced

Figure 8 – Trade Show Exhibit Desk

to support the marketing visits and demonstrations.

Two major electronics trade shows were scheduled for the spring of 1976. The key International show was Comm 76 taking place in Brighton UK during June 8 – 11, 1976. Marketing meetings would precede the opening of the public event. An HF-80 system would be unveiled and demonstrated.

Collins traditionally exhibited at the annual Armed Forces Communications and Electronics Association (AFCEA) held in Washington, D.C. The 1976 show was also scheduled for June, 1976. An engineering model live demonstration HF-80 1 KW Station was set up in a private hotel room. Select customer personnel were invited to the private

Figure 9 - Promotion Photo—Office Environment

showing away from the eyes and ears of competitors.

Following Comm 76, Rockwell/Collins marketing and engineering staff started an extensive tour of a number of international markets and customer locations in order to effectively introduce the new HF-80 Product Line and look for near term and future business opportunities.

A complete set of demonstration equipment was shipped overseas and then the engineering and marketing crews would rotate in and out of overseas assignments manning the demonstrations. The Rockwell/Collins International sales offices provided customer contacts, scheduling, and follow up visits.

Production Transition

Following the introduction of HF-80, marketing set about filling their order books and worked with potential customers while engineering, manufacturing, and product support moved toward production. An engineering test bed was established with on-the-air testing on a 24 hour per day schedule. This proof of performance testing was de-

Continued on p 48

Casper & the KWM-380

by Dave Berner

The High Frequency Communications Systems Market is a non-homogeneous grouping of specialized commercial, government, and private applications. The lower cost portion of the market continuum consists of fixed channel commercial and industrial applications, amateur radio hobbyists, and general purpose receivers for a broad customer base. Collins Radio Company had pursued these markets in the past but did not have any current technology product offerings available in the mid 1970's.

I had been the lead for the HF-80 Series Product Line program that had just completed the market introduction phase of development. In August, 1976 the HF Products Director, Gary Jost, requested that I would take on a new assignment. That assignment is another whole story. However, the business planning approach used with the HF-80 program provided a valuable experience base for the challenge ahead. The company environment had changed to a profit/market driven business model. My challenge was to lead a team to explore the feasibility of pursuing lower cost HF equipment market niches. Anticipated outputs of this effort were business plans addressing fixed channel transceivers, and General Purpose & Amateur HF Radio transceivers.

to provide a competitive edge, the HF-80 (ISB) Project had been kept under wraps as development progressed and was not revealed until market introduction. Likewise, the "low cost HF" was to be kept quiet. The name Casper was chosen for use when referring to the project. The team was located in a common closed area with limited access.

As I reflect on the project it was a rather daunting task. Although some of the guiding principles learned on the planning and development of HF-80 would apply to Project Casper, it would be much more complex. We were dealing with three different market segments with different customer characteristics. The team members had to be market researchers to gain a broad understanding of each of the market segments. This approach to a development project was new to most of the assigned staff. In addition, the directed overall schedule was very aggressive compared to HF-80.

A multidiscipline business team was put together to do a business feasibility study that addressed the three different low cost HF niche markets. The feasibility study concluded: 1 - The market opportunities were real and quite competitive. 2 - Collins H-F Products had successfully competed in the past but more recent competitors' products had an advantage. 3 - Technology was available to design and develop competitive products using a common design base. 4 - Changes in distribution/marketing would be required. 5 - Potential financial returns looked favorable. 6 - Reestablishment of Collins HF Products as a viable competitor in these markets had the potential to reduce competitive encroachment on other addressed HF market segments.

PRODUCT/MARKET SEGMENT BUSINESS PLANNING

Management approval to proceed with the detailed business plans triggered the Program Team into action. Team personnel remained constant to maintain program continuity but were augmented by the assignment of additional functional support personnel. Key personnel were located in a closed office area with laboratory facilities.

The planning task was segmented into five sub-plans with staff assignments as shown at the conclusion of this article.

Since the program dealt with three distinct product/market segments from a common design base, the planning complexity was almost tripled. Individual sub-plans relating to each of the product/market segments were developed. Except for those differences directly related to the individual market segments, the team applied commonality principles in the planning process.. This approach was particularly challenging as each of the plan elements required a fit test and impact analysis on the related plans. Professional teamwork was a key factor in dealing with the inherent conflict of the defined task elements.

CASPER Program Manager: Dave Berner
Production Facilities Study: Roger Grinstead

Receivers Prod. Mgr: Dave Jaksa

Marketing: Jim Perkins
Marketing Support: Bob Gehring

Operations: Harold Hauglie
Operations Support: Ron Weuve

Product Support: Herb Ransom

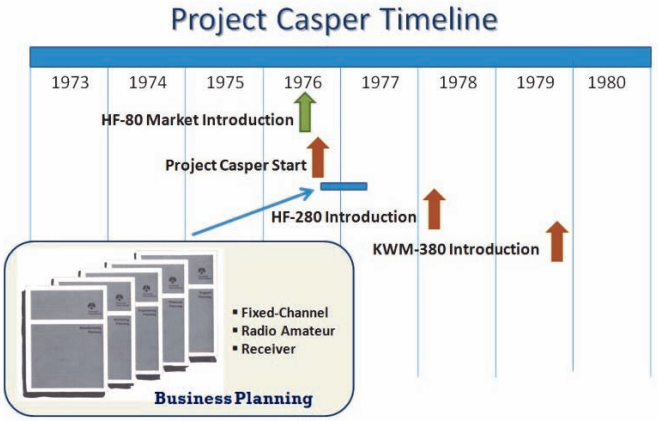
Finance: Paul Goddard

Engineering: Dean Anderson
Fixed Channel Project Engineer: John Koskela
Amateur Radio Proj. Eng: Bill Weaverling
Receiver Project Engineer: Bill Sabin
SMO Design Engineer: George Moger
Solid State Power Amplifier Design: Don Herr
Antenna Coupler Design: Jerry Knight
Industrial Design: Darrel Schultz
Mechanical Design: Herm Nebiker
Component Engineering: Darrel Olson

Perspective: Fall, 1976

Representative competitive products were purchased and analyzed in terms of features, performance, and cost to produce. The business approach used by perceived key competitors was analyzed to determine operating methodology, strengths and weaknesses. Product designs including schematics, mechanical space utilization and industrial design models, preliminary lists of material, and projected cost estimates were developed. Production operations planning focused on the requirement for a low-cost commercial factory environment which would be a departure from the mainstream business factory environment. Marketing planning focused on strategy development to achieve a new market presence and unseat competitive entrenchment. Support planning focused on developing a responsive and competitive service and support posture. Financial planning focused on forecasted sales, related estimated costs to launch and sustain the program, and anticipated financial returns. In addition, a complete risk assessment was provided to guide future strategies and tactics. This risk assessment dealt with both the internal and external environmental factors, including the economy and the competition.

The sub-plans were consolidated into a business plan for each of the three product/market segments. A total venture business plan was the result of consolidation of the three business plans. The result of this 27 month planning process was reflected in seventeen volumes.



PROGRAM IMPLEMENTATION

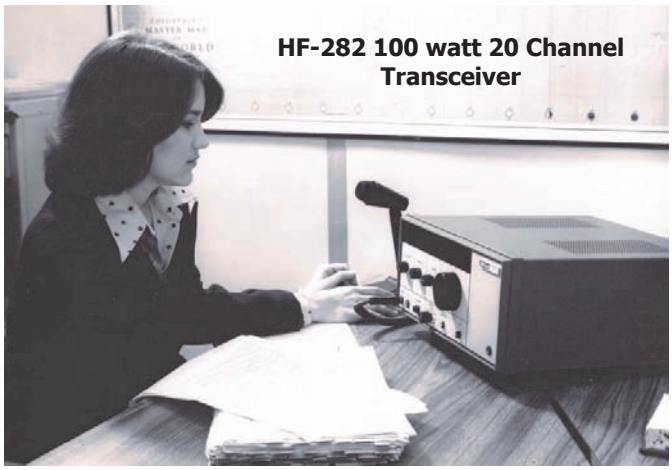
After Management review of the business plans, approval was given to proceed with development. The program office activity switched from planning the work to working the plan. In addition to the new development activity, the program office was given the responsibility of managing the existing products business which would be replaced by the new products under development. In a sense, the program office was responsible for three unique businesses or "little companies". Each business addressed a given product/market segment and had a unique" set of business challenges in addition to the common bond of new product development and future shared usage of production facility.

The "Fixed Channel Co." was to form a new business by developing, introducing and producing a new product line in a market not actively pursued for a decade. The "Amateur Radio Co." was to manage the

current ongoing business with relocation of existing production to a new commercial manufacturing facility, phase-out existing 20 year old products (S-Line and KWM-2(2A), reestablish a unique distribution network, develop, introduce, and produce a new product line. The "Receiver Co." was to manage the current ongoing business, develop, introduce, and produce a product which was part of the new product program related to all three "companies". This new product was to replace the 51S-1, another 20 year old product, which was to be produced and relocated to the new commercial facility.

All three companies were faced with the challenge of: (1) New commercia1 factory; (2) Requiring a mindset change in all involved personnel to recognize the competitive commercial nature of the venture; (3) Implementing a consolidated service/support center, and (4) Planning for long-range product line expansion.

The baseline new product plan called for parallel development of the new products for each of the three "companies". Two program external factors precipitated a major strategy/schedule revision to the plan. Other program priorities which developed in the HF Business Area required additional engineering resources and the international marketing organization suggested that product introduction be made the following March (planned introduction was October). Both factors realigned program priorities and the emphasis was placed on the



HF-282 100 watt 20 Channel Transceiver

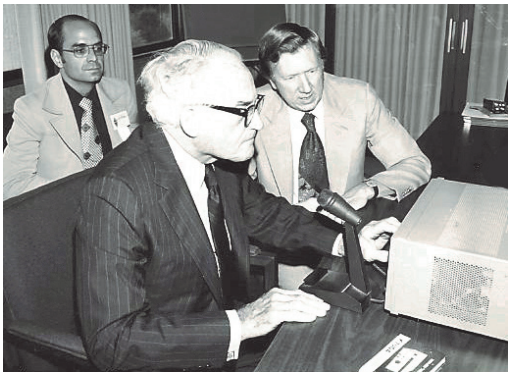
"Fixed Channel Co.'s" HF-280 Series product line.
In the next six months, a commercial factory was secured in El Paso, Texas. Production of existing S-line and HF receiver products were transferred to the new facility, and the new HF-280 series products were introduced seven months ahead of plan. The introduction was scheduled to coincide with the International Communications and Electronics Show in Birmingham England in the spring of 1978. Market reaction at the introduction and nine subsequent world-wide events was very supportive and order backlog began to grow.

Subsequent to the introduction, program office effort focused on completion of the planned product line development which included six major products, sixteen options, twenty-one accessory items, and three customer test equipment items. Marketing literature and sales tools were completed. An associate Program Manager was brought into the program office to assist with production transition.
In the ten months following the HF-280 Series introduction, major challenges surfaced in the production transition. The program team was working with new products new factory, new personnel (new to the program, HF Products, and Company methodology), a new data system, and geographic separation of the development and production teams. This along with the other program demands placed on the program office precipitated a realignment of program management responsibilities. . An additional program manager was assigned to the now ongoing production business of "Fixed Channel Co.'s" and "Receiver Co.'s" products. I was to focus on the development and introduction of "Amateur Radio Co.'s" products and close down KWM-2(2A) production. During the following months, the key challenges faced were directly related to the HF-380 Series and implementation of the new factory in El Paso, Texas.

As the Amateur Radio Program Manager, I focused on the development of the new products, dealer network, service/support center, pilot production, and product 'introduction. There was a consensus that there was a latent market interest in a new, state-of-art "Collins" Amateur Transceiver. The Casper Project had been under wraps since its inception. Prior to the planned market announcement at the scheduled Midwest ARRL Convention, teaser advertising was placed in Amateur Radio Periodicals. During the week prior to the convention, all Collins Amateur Dealers were brought in to Cedar Rapids, Iowa for a comprehensive seminar covering all aspects of the new Rockwell-Collins Amateur Products.

ARRL Convention - Cedar Rapids, Iowa in October, 1979

The convention was well attended and an exciting time for attendees, dealers, and especially those of us involved in the development and production of the new products. The "radio factory" continued to be abuzz when all returned to work the following Monday.



Here, Barry is shown with Dennis Day & Rod Blocksome trying out his new KWM-380 Serial #1

One of the many highlights of the Convention was the attendance and banquet keynote address by Senator Barry Goldwater, K7UGA.
The Convention Committee arranged to present Senator Goldwater with one of the first KWM-380 Transceivers as appreciation for his participation in the event. He spent some on-the-air time before the evening banquet. Rod Blocksome (W0DAS) was convention host for Senator Goldwater.

Marketing planning included development of advertising literature, presentation material, brochures, logbooks and hand-out items. The amateur radio dealer network was reestablished and a comprehensive dealer seminar held in Cedar Rapids prior to the ARRL Convention. The KWM-380 and HF-380 Transceivers were introduced in October 1979. The positive market response was overwhelming and underscored by receipt of orders in excess of 90% of the planned first year's production of 1,200 units.

In December, 1980 I was assigned to the position of Manager, HF Ventures Planning. New business opportunities were available for the Rockwell-Collins HF Business Area to address and my future changed direction again. - - - - - - - - - - - - - - - - - CCA - - - - - - - - - - - - - - - - -

1979 - 1983

UHF at Collins Radio (Cont'd)

The AN/ARC-159 (Figure 7) was a good example of a communications interface that could be easily operated by a busy crewmember. The ARC-159 was a very compact one unit R/T + Control that featured a digital frequency display, and toggle switches to manually set frequencies. This radio was the first all solid state UHF aircraft radio in the Collins lineup, and probably the first SUCCESSFUL solid state UHF AM radio period! (The Signal Corps light helicopter radio series (LHR) AN/ARC-116 had been a disaster) The ARC-159 served well with the Navy, until operational requirements forced the adoption of anti-jam frequency hopping waveforms, such as the Magnavox *Have Quick*, becoming the DoD standard.

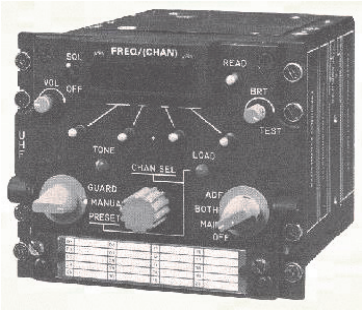


Figure 7 - ARC-159 R/T, 1972 to 1977

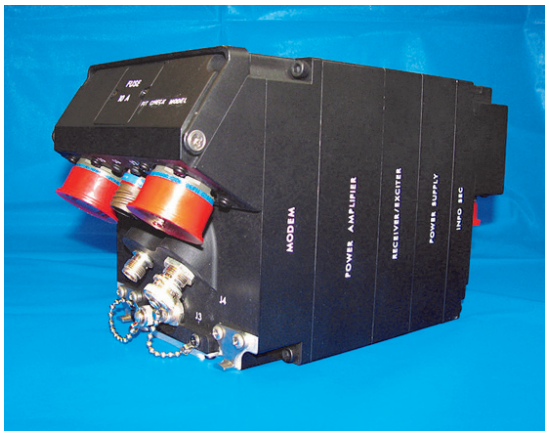


Figure 8 - ARC-210 R/T - 1989 to Date

Currently, the Collins AN/ARC-210 (Figure 8), in various incarnations, bears the brunt of the US military's tactical airborne communications traffic. The ARC-210 is perhaps a bit out of place in this article, since its frequency range is 30-512 (940 now available) MHz, and it is capable of a multitude of modulation waveforms, ECCM, and also has embedded encryption capability. All of this happens in a package not much larger than the ARC-159. The ARC-210 can be configured with a high power PA for Satcom use as well.

Any discussion of UHF tactical communications could be considered incomplete without mention of the ground and vehicular elements, but this is perhaps for another day. However, the PRC-66, one of the smallest UHF handhelds is shown here as a teaser.

Figure 9 - PRC-66 Toronto

When one considers the scope of the financial impact that the UHF product lines at Collins have had on their total revenue stream (See the inset upper right), it is clear that this was a very significant product category at Collins, both in the past and still today. In addition, it also gives one a unique insight into the technology of the company. When you consider the importance of what may have been the sole communications radio installed in some tactical aircraft, it is a worthy subject for discussion.

de Scott, W7SVJ - - - - - - - - - - - - CCA - - - - - - - - - - - - - - - -

I wish to thank Don Gallagher & Dave Keese, retired UHF Eng. Group Heads, for their help with this article.

UHF Product Business Impact:

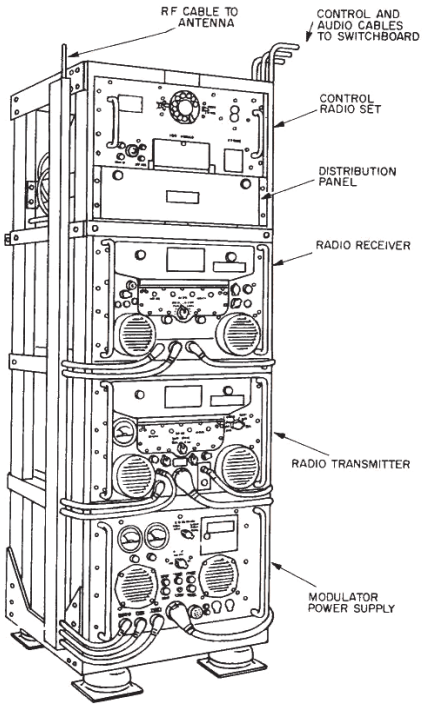
ARC-27 (1946 to 1952) - 40,000 units manufactured by Collins and 35,000 additional units manufactured by two subcontractors. The maximum revenue per year peaked at $24M and the total program value is estimated at over $65M in 1952 dollars. ($554M in 2012 dollars)

ARC-159 (1972 - 1977) - Over 5000 units manufactured in less than two years. First all solid state panel mounted UHF radio.

ARC-210 (1989 Development/1990 Contract Date) - Over 20,000 manufactured for a total program value of over $1,000M.

Ground UHF at Collins - Then & Now

GRC-27 (x)
circa 1952
UHF Transmitter
Receiver - 100 Watts
225-400 MHz
1750 Ch.
100 KHz
Wt. 600 lbs.



RT-980/GRC-171
circa 1975
UHF Transmitter
Receiver—20 Watts
225-400 MHz
Wt. 75 lbs.

Rockwell Collins
Software Defined
Model 721S
30-512 MHz
Transmitter Receiver - 100 Watts
Options to 8.3 KHz Channel Spacing

40 lbs

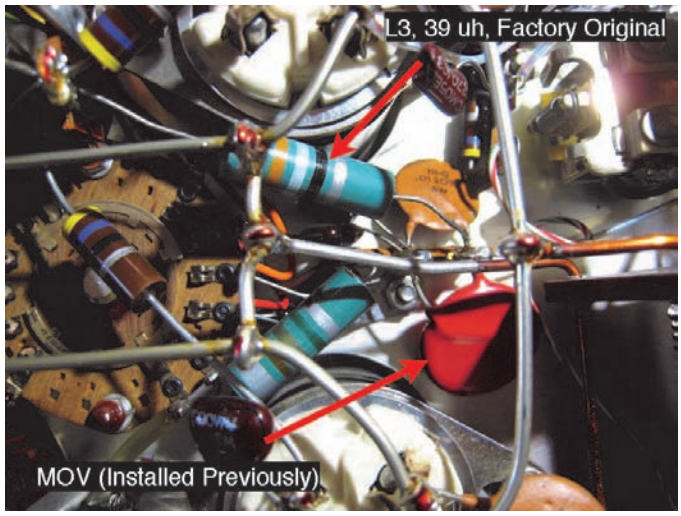
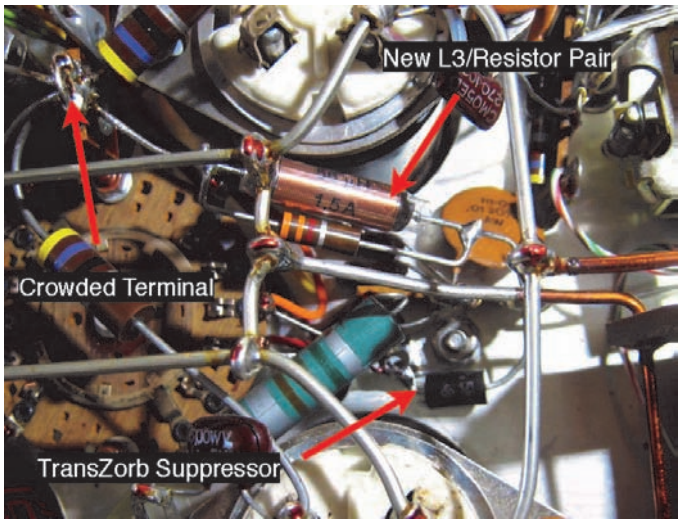


Figure 4 & 5 – Circuitry (Before Above) & After Mod



One concern over this modification was whether it might affect the behavior of the ALC and/or the Tune Meter function of the 30L-1. Fortunately, we found very little change, if any, after the modification. However, I would recommend checking the behavior of both functions and adjusting R16 and C18 if required.

Comments and Conclusions

The 30L-1 is not unconditionally stable, and was not designed to be. Two stability issues were identified. The first of these occurs in the upper HF frequency range, and can be avoided by attention to the output load, and in some cases, the input termination. This oscillation only occurs with improper setting of the Tune and Tune controls or a poor VSWR at the 30L-1 output. Although neutralization may help (check out W8JI's website), neutralizing an existing a 30L-1 would be difficult from a mechanical standpoint. In general, the HF oscillation typically occurs when operating on the 10m or 15m bands. It usually will not occur if the 30L-1 is properly tuned and its output is terminated with good load at the operating frequency. However, in the case of Dave Harmon's unit, the length of cable between the driver and 30L-1 made a difference.

At one time, the 20.5 foot cable was specified for use with the 30L-1 amplifier, but in this case the cable was used to improve stability, not the IMD improvement for which it was originally implemented in the 30S-1 system. Early in the 30L-1 manufacturing cycle, component changes allowed the 20.5 foot cable to be deleted from the system requirement. Dave Harmon's experiments indicated that the length of cable between the 30L-1 and driver might indeed have an affect on HF stability, at least in some 30L-1s.

The MFO instability is a lower power phenomenon that occurs between 700-900 kHz. This oscillation is troublesome because it may occur on any band even if the 30L-1 output is terminated with a good load at the operating frequency. It is at a low level compared to the primary transmitted RF voltage, so you have to be looking for it. I found it with an oscilloscope while monitoring my output. It is most prevalent and has the highest amplitude when the 30L-1 is on 80m and terminated with a load that is high impedance at 700-900 kHz. This MFO was present on 5 of 5 units tested, so you are likely to have the problem as well. You don't want to be transmitting in the AM broadcast band!

Another Benefit: After installing the L3 modification, an additional perk was noted. In my 30L-1, and Dick's, we found that power output on some WARC bands went up significantly. On 12m, my maximum output power increased by about 1/3. Dick saw even more improvement in his 30m output. Although I'm not positive, the improvement is likely due to the fact that the new grid choke has a 70 MHz SRF. I measured the original 39 uH choke SRF at 25.8 MHz. It certainly seems likely that this SRF could have been adversely affecting 12m power output.

In a July 1970, Collins released Amateur Product Line Information Letter #26, which changed L3 from 39 uH to 22 uH. Although the document does not give much detail, the change apparently was incorporated to fix a parasitic instability unique to a late production run of 30L-1s. It was not meant to address the MFO discussed here. Spice analysis shows changing L3 to 22 uH increases the grid resonant frequency, stopping the MFO with some Tune/Load setting, but it makes the problem worse with other settings.

Dick found something very interesting concerning his Heathkit SB-200. It uses a pair of 572Bs, but much of the RF circuitry looks like it was taken directly from the 30L-1 schematic. It uses a grid choke of 28 uH with a 3.3k resistor across it. Hmmm… Out of curiosity, Dick temporarily removed the resistor, and the amplifier produced a very similar bursting MFO to the one we observe in the 30L-1.

Although the MFO mechanism is well understood, the precise cause of the burst behavior is not. Clearly the bursts are associated with AC line sources since the bursts are synchronized with the line frequency. There are quite a few sources that can contribute to the bursts, which are characterized by complete "ON" and "OFF" cycles of the MFO. The list includes the obvious HV ripple and bias ripple, as well as characteristics that are present in filamentary-cathode (directly heated) tubes heated with AC. These characteristics include filament emission variation due to AC heating, interaction between the magnetic fields of the space charge and the filament, the electrostatic field of the filament, and resistive filament imbalance. Dick performed an experiment in which he heated the tube filaments with DC rather than AC. The result was that there was no bursting of the MFO, although the MFO modulated with ripple was present. It is therefore reasonable to assume that although the HV and bias ripples may be secondary influences on the burst mechanism, the primary driver is related to the filamentary-cathode aspects of the tube. After discussing the burst mechanism with Bob Kellow and further analysis of the Spice model, the most plausible theory is something like this: A combination of the aforementioned phenomena produces a 60 Hz voltage, Vac, that varies the tube grid-cathode potential, Vgk. The MFO initiates at a slightly negative value of Vgk. As Vac swings Vgk more positive into the region where grid current begins to flow, grid conductance increases, lowering the Q of the grid tank and quenching the MFO. When Vac returns Vgk to a more negative value, MFO re-starts. Eventually, Vac swings Vgk far enough negative to lower the plate current to a value that once again quenches the MFO. Repetition of this process results in the 120 Hz bursts. The Spice model supports this theory, but the tube model used does not have sufficient detail to produce the exact burst behavior we observe in the 30L-1. Of course, the burst mechanism is only of academic curiosity since elimination of the MFO also eliminates the bursts.

Acknowledgements: Thanks go out to Dave Harmon, K6XYZ, for his input at the start of this investigation. I'd like to give a very special acknowledgement to the efforts of Bob Jefferis, KF6BC, and Dick Weber, K5IU. They invested a huge amount of time in this project. Thanks guys. I couldn't have done it without you! de Don, W5QN

CCA

Why did these 50 airlines order Collins Flight Directors?

ACTUAL SIZE

Because Collins' three-dimensional Flight Directors (the FD-109 is shown here) give aviation its most advanced approach to all-weather landings. A natural, human-engineered V-bar indicator presents positive steering commands from takeoff to touchdown. The system provides a constant visual picture of aircraft attitude and position. The 3-D concept eliminates parallax.

Proven in service around the world, the FD-108 and FD-109 are the latest in a long line of Collins flight director systems. Both are certified for Category II operations.

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signed to look for potential operational anomalies and initiate corrective action before full production. Manufacturing set up their assembly and test procedures and instructions. Parts were placed on order. Product support implemented their strategies towards enabling customer friendly support resources. Production assembly and test personnel were put in place and trained. Result: Production began - and

Figure 10 - Dennis Day, Group Manager stands proudly in front of the display of HF-80 gear at Comm 76 in Brighton, England

the first HF-80 equipment was delivered - in the spring of 1977.

HF-80 Program Management Transition

In August, 1976 the HF Products Director, Gary Jost, requested that I would take on a new assignment. That assignment is worthy of, and is in this issue, another whole story. However, the business planning approach used with the HF-80 program provided a valuable experience base for this challenge ahead. The company environment had changed to a profit/market driven business model which had resulted in an entirely new Product Planning methodology. My new challenge was to lead a team to explore the feasibility of pursuing lower cost HF equipment market niches. Anticipated outputs of this effort were business plans that addressed fixed channel transceivers, Amateur HF Radio transceivers, and general purpose HF receivers.

Mr. Ed Rathgeber was designated the replacement HF-80 Product Line Manager to carry the ball forward and manage the next stages of the product life cycle. This is a continuing story.

- - - - - - - - - - - - - - - CCA - - - - - - - - - - - - - - -

Epilogue

Although my primary attention was thereafter directed toward other opportunities, I couldn't help but have a latent interest on how HF-80 business ultimately played out as the years progressed. The key question was *"how did we do compared to the plan?"* In Summary: A commercial position was achieved and recognized by the U.S. Government. Product line extensions were developed to address expanded niche markets. Cumulative orders by 1990 were more than $ 234 M exclusive of international licensing. (Remember, the original goal was $53M) Gross profit margins were a significant contributor to the division's operating profit over the HF-80 product life. Economic benefits were provided for Rockwell Stockholders, company employees, and the local businesses. As I look back, I am impressed with and appreciative of the team effort that was put forth to make HF-80 a success.

Editor's Note: It is also significant that the HF-80 program was probably the first in house funded program to be planned and developed under the new "Wilson/Rockwell" culture. It can only be described as wildly successful. We are indeed fortunate to get the insight of the man that planned it. This insight not only reads on the HF-80 project but also gives us a real feel for some of the changes which hit Collins Radio when they were merged into Rockwell.

Attached here is also a summary of production volumes that were provided by Rod Blocksome, who - some years latter – summarized the results of this significant program in a report that now resides in the Rockwell Collins Museum.
This report was done in 1995 after the conclusion of the program.

Extract courtesy of Rod Blocksome:

1kW Tube Transmitters (PA, PS, Exciter or R/T) = 1,500
1kW Solid State Transmitters = 800
3kW Transmitters = 95
10kW Transmitters = 1500 (includes 475 FRT-96 + 10 HF-8151A)
Receivers = 4000 (includes the 851S-1)

The Rockwell Effect -

(Cont'd from page 9)

and a feather in the cap of the Rockwell management and technology efforts. It had brought Rockwell hundreds of millions of dollars of profitable business, but even that landscape was succumbing to the high levels of integration brought on by Moore's Law and the death of the FAX machine.

Now we get to the other half of the Happy Ending of the story. At the turn of this century, the Rockwell International Corporation went through a "Spin Out" process, breaking itself into two separate publically held companies – Rockwell Collins and Rockwell Automation. Rockwell International had concluded that the individual entities could make better decisions and be more responsive to their own, and customer's, needs if they were stand-alone entities. On June 29, 2001, Rockwell Collins was again the master of its own future. That following Monday, July 2, 2001 - at the start of business on the New York Stock Exchange - the old Collins Radio NYSE call of "COL" was once more on the Big Board.

During that 22 year span between the merger of Collins Radio and the eventual spinout (and rebirth) of Rockwell Collins, Inc., the company remained – other than strategic divestitures and acquisition – relatively intact. Collins' core technologies, and more importantly the culture of excellence of its people, products and quality survived…. but now infused with the Rockwell business culture.

In spite of the markets exited, sales over those 22 years grew from $350M the year just prior to the merger, to an astonishing $2.5B in 2002 (the first report year after the spinout), and then to $4.73B in 2012 – the last reported year. What is really impressive is the fact that, even given the flat sales following the 2008 collapse of the global financial markets, the Rockwell Collins margins and reported Net Income as a percent of Sales (before taxes) have remained at an average 13.2%. Contrast this to the much lower returns of the Collins Radio Company of the late 60s where "good" Net Income returns were in the 3% range and, in bad years, they went negative.

Editor's Note:

There are many stories here that have gone untold , or summarized, due to space limitations. Following this series of four 80th Anniversary Issues of the Signal magazine, there will be expanded versions of this "era" history that will be placed on the Collins Collectors Association website at collinsradio.org. Specifically the stories of the management structure that ran continuously spanned from the Collins Radio days until the rebirth in 2001, the longer version of the MODEM story and the here untold story of GPS, will be added to the historical perspective. There are, as you might expect, some fascinating details imbedded within those summary financial numbers shown above.

Rockwell Collins

IN THE ROCKWELL COLLINS SHACK

Located in the SSB shack of the N7OTQ/K0CXX operating and display building, these two positions represent some of the best HF Comm gear in the world. The HF-80/TSC-60 (V) shelter cabinet on the right houses a complete 1 KW HF-80 Solid State system including HF-8054A 4 Channel ISB Receiver and the companion HF-8014A 4 Ch. ISB Transmitter. These are interfaced to the HF-8064B Preselector and the HF-8023 1 KW Solid State PA. The lower unit just out of the photo is the HF-8032 Power Supply for the 8023. On the left is a Rockwell 718U-12 system incorporating the 671U -4A Receiver/Exciter and the 514A-7 digital control head.

Jim Stitzinger, WA3CEX, (left) standing beside his HF-80 suite of equipment that is completely operational and includes all of the basic units of the HF-80 system, including the 1 KW tube (behind Jim) and solid state PA units as well as the 3 KW and the 10 KW PAs which are not pictured here. In addition, Jim has a rare example of an operating Navy 10 KW HF-80 transmitter, the FRT-96/HF-8151A. Below left is the business end of his AN/TSC60 (V)7 Comm Central Communication Shelter—also fully operational. Jim has been kind enough to bring this shelter and its companion diesel generator to a number of our conventions and CCA shows. Left inset is Rod Blocksome working on the FRT-96/HF-8151A.

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The brakes: Now Pinto gives you front disc brakes as standard equipment—for efficient, fade-resistant braking, with little pedal effort.

The ride: We've refined the suspension both front and rear—with a new package developed specifically for the '74 model.

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See the Pinto at your Ford Dealer. 2-door sedan, 3-door Runabout, and the popular Pinto Wagon. With improved basics for 1974.

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FORD PINTO

FORD DIVISION Ford

(Shown here: 1974 Pinto Runabout, with optional Sports Accent, vinyl roof and deluxe bumper groups.)

Collins Collectors Association

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Serving the Dedicated Collector

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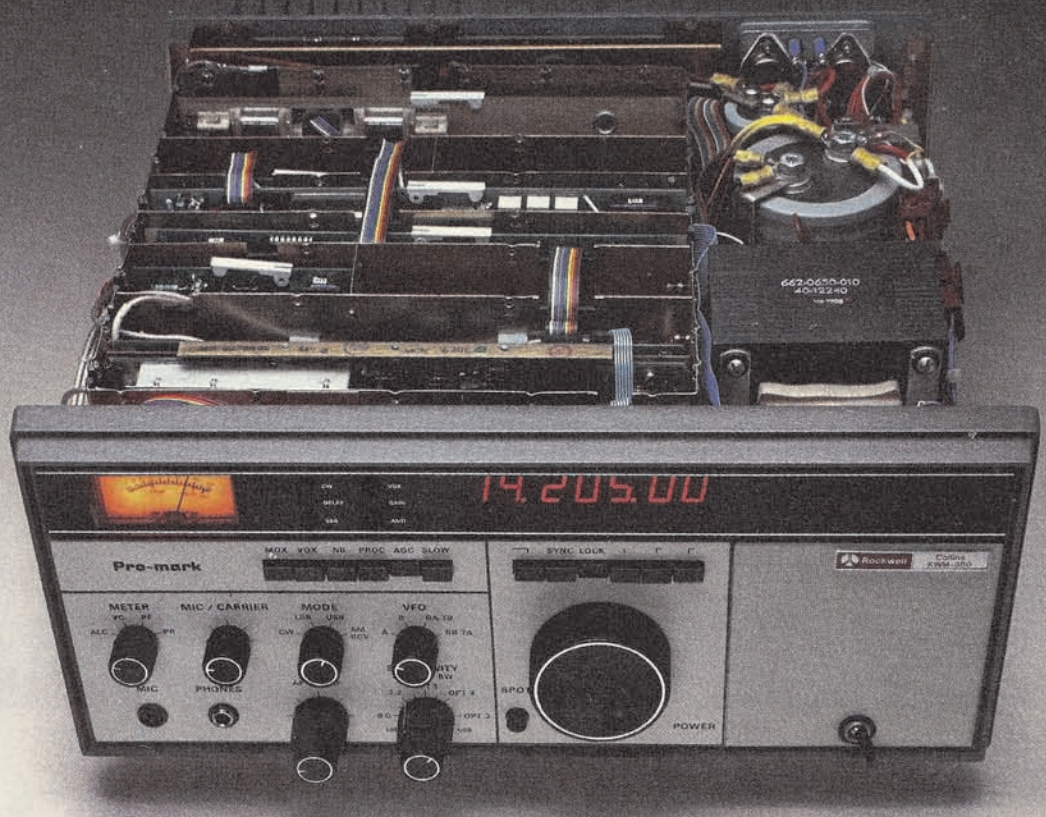
Those were the Days
Of Impressive New Technology -
Some of it Lasted

The real beauty of the Collins KWM-380 is behind the panel, not on it.



At Collins, we know serious amateurs won't settle for less than professional performance. So we build every KWM-380 to commercial rather than amateur standards. For example, our PC boards are connected by ribbon cables with gold-plated pinfield connectors. The boards themselves are all glass epoxy, and virtually

unaffected by temperature and humidity which cause intermittents in the more commonly used phenolic boards.

Once built, every KWM-380 undergoes 24-hour burn-in, then is aligned and tested to meet or exceed every spec on the data sheet. Which makes us very confident about warranting your KWM-380 for one full year.

The result is a radio with superior performance and lasting quality, not front-panel glitter. Frequency stability is just one example of its beauty: typically, drift is as low as 10-12 Hz per hour for normal ham shack environments. Other companies haven't matched our performance because they don't match our quality behind the panel.

Add some real beauty to your station. See the KWM-380 at your nearest authorized dealer. Collins Telecommunications Products Division, Defense Electronics Operations, Rockwell International, Cedar Rapids, IA 52498. Phone (319) 395-5963. Telex: 464-435.

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