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Interview with Ed Nossen

RCA Heritage Program

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[0:00:08] Edward: Okay, my name is Edward Nossen and I came to RCA in 1955. I was offered two positions; one in Camden and one in Moorestown. Moorestown at that time was air-conditioned, Camden was not. That was the decision maker. But I worked for the airborne systems division, which was located in Moorestown at the time. I started reading about air defense fire control. I've come from a non-military background, so this was all new to me. Looked at the Falcon missile system and how it was implemented that the missile auxiliaries and came up with a solution to greatly simplify the number of boxes by time sharing the checkout of the missiles didn't need to them all simultaneously. Generally they weren't shot off simultaneously. Then I was loaned out to M&SR just down the hall.

[0:01:53] They had a problem with the Talos land-base system; in particular, the missile guidance radar. The problem was with the ConScan notation servo. It wasn't working too well and didn't work at all at -40 degrees. While I was getting into the servo business, I was taking a course of Drexel as part of my Master's program in servo theory. So I started to look at the servo and it seemed to work all right a normal operating temperature. But it didn't work at all at low temperature. The shaft just froze. After checking everything out, I realized that the speed control used the field control, couple of tubes like 6L6s were driving the field, and when speed was low or it would stop, field time was reduced and at the same time the torque was reduced, so there was no way out. Now, I'd spend the summer working for Boggs Electric and they build motors, generators, combinations. I became familiar with Ward-Lenno system where you have a generator driving a motor. Instead of the field, you control the armature from the generator.

[0:04:08] I suggested that to management and they said, "Nah, we don't have the money. We don't have the time. See if you can fix it without…" I managed to convince some of the other engineers in the servo group and there was a spare generator on the large assembly which had generators for the angle track or something so on, and we jury rigged a Ward-Lenno system and it worked. Minus 40 degrees it broke loose and started up. Of course once I gave a demonstration to management, they said "Okay, let's put manpower on it and let's get it done." We had to deal with the supplier of the generators and motors, I believe it was Singer, come up with the right specs. Eventually, that worked out. In the process of fixing the servo system, I realized that there was jitter in the system because the bandwidth was too wide so then the signal to noise ratio was low. Reducing the bandwidth fixed that part but made acquisition much slower.

[0:05:59] I came up with a very simple concept, change the bandwidth. When the signal is large, have a wide bandwidth; and when the signal is small, and it wouldn't improve the signal noise, reduce the bandwidth. All it took was a capacitor and a Zener diode. Zener diode was the threshold. Once it exceeded the level of the Zener diode, the capacitor was cut out and now we had full bandwidth. Then I went back, after that project, I went back to airborne systems, and we were thrown out by the radar division because they needed the space. We wound up going back to Camden. I found myself in a newly organized systems group with one of the activities being ECM and ECCM. I have no background in that, but I learned on the job or rather learned on the proposal. The first thing that happened was we got a request for a proposal to come up with a ECM suite, receivers, jammers, and so on for the B-70 aircraft.

[0:07:56] The only activity in RCA that was involved in that kind of technology was on the west coast, Van Nyes. So I went out there and I believe they may have been the prime on it but I learned about jammers and supporting receivers, and so on. We lost the B-70 bid. We just didn't have the depth of knowledge. There were other companies that had been in that business for years. In fact, Sperry was building a large integrated system for the B-52H, which was then just coming off the assembly line. I decided to take a look at what they had on the other B-52's and it was very antiquated. They had as many as nine tuners, had one display. The operator switched from one tuner to the next trying to detect a hostile signal and then put a jammer on it if it was suspect. At the time of the B-52G's were the latest, they were flying and had that technology on it.

[0:09:55] I did some thinking and came up with a concept of having all tuners sweep simultaneously. It took two seconds to sweep from one end of the band to the other. I checked out DuMont and what they had in airborne direct-view storage tubes and I came up with an unsolicited proposal, which was submitted to the air force for use on the older B-52's like the G and earlier ones. We presented the concept and it was filed away. A little bit later, the B-52H system that was under development, was getting too heavy, too expensive, and the air force canceled it. Now they had an empty hole in the B-52H. Then somebody remembered there was this unsolicited proposal somewhere in their drawer, and they dug it out, we got a call, "Would you like to come and give a presentation on that?" They also asked a few other companies if they had any off-the-shelf or near off-the-shelf equipment that could be used. We won the job and we built a couple hundred systems. I have the original brochure here, which was classified back then.

[0:12:14] Counter-measures receiving SEP AN/ALR 19. Block diagram, picture of the display, and here is the actual display. There were a number of scans going on simultaneously. All they were doing was scanning. There were two, one for x-band and one for fore and aft, so we displayed the fore up and aft down on the same trace. Years later, the Air Force decided that the two-second scan was too slow and we had built experimental models of voltage tuned receiver so that it could be swept much faster. Unfortunately, again, we lost the… that was the ALR-20, we lost that to Loral who had built the original tuners and they didn't sit still.

[0:14:03] They were gunning for replacing the LM-19 when the time came; this was in the 1960 time period. The other thing that I did in that time period for this business was developed a warning receiver for aircraft. The existing warning receivers only told the pilot or the second-seat operator that there was a signal didn't tell them what it was. We came up, at that time, I had a couple of people working, with a receiver that included a processor and we had matched filters for different threats, so it would display: This is a surface-to-air missile, this is an air-to-air missile, and other threats of that type based on the latest intelligence. About that time, the systems group was split and the ECM activity was moved to Burlington, Massachusetts.

[0:15:56] I was offered to go up there, and after looking into it, decided to stay in Camden. The cost of living was much higher in the Boston area and there were some other reasons too. The warning receiver activity that we were working on went to Burlington and one of my key engineers went with it. Eventually, he wound up flight testing it in Vietnam in the second-seat of an F4, and it wasn't too comfortable when the Mig came after him, because there was civilian on board, they weren't allowed to engage and had to return. But the system worked and told them what was coming based on the radar emissions. One day, I got a call from people in Moorestown that were working on BMEWS. They said, "We have a problem with BMEWS. It can be a jammer coming in through the back lobes of the antennae, and we won't know about it. We need something to detect jammers 360 degrees so we can take action. But it wasn't budgeted and we're in a time bind, so it's going to be used indoors, mostly indoors.

[0:18:05] We could use a commercial equipment." So I started out with a Polarad spectrum analyzer, that was our receiver. I got eight directional antennas and that frequency band of about 400 MHz. Built a switching system so that you can scan through the antennas and stop, and it worked. It was delivered to the various sites. Never heard about jamming reports, but they did find an electric razor in a barracks that was putting out noise, so the system worked. Another job around that time was from the army security agency, they came to us. RCA reputation and RCA had high-power hardware. Their basic question was, this was during the Vietnam war time, "We want to be able to jam Vietnamese television and we want to be able to substitute our own programs.

[0:19:58] We have no idea how to do it, but whatever it is, it's got to be transportable in a C-130." So we didn't know what was the best way to jam television. We had a psychologist working for the systems group and he said, "Yeah, I can devise a test and we'll go from there." We wanted to test audio and video, and he recruited a number of students from Rutgers as the test subjects. For video jamming, we actually broke it into two pieces. One was attacking the sync, the other was attacking the video. The sync, we could do in the lab, we didn't need any subjective idea. For the video, we came up with a number of pictures, simple pictures: a car, a horse, a child, a long list. There was also a list with numbers and check off what you think you see.

[0:21:57] We ran a number of different jamming wave forms, white noise, and others, and got the response where the video was no longer intelligible. In parallel, we were doing tests on the horizontal and vertical sync wave forms, and they were much more vulnerable than the video. You could tell with a noisy picture what was there, but if the picture was rolling or horizontal sync lost and if it's diagonal lines, there was nothing there to see. Based on energy needed, the sync was the most vulnerable. We came up with a paper design for a total system. We didn't go beyond that but they wound up buying broadcast transmitters from our broadcast division, and they had to cut them down to size to fit in the airplane, but that's what they used. Along the same lines, we got a call from, I believe it was the navy organization in Indianapolis, vague recollection. Anyway, the object was we have this Maverick missile and eventually they built 80,000 of them with many modifications, different seekers, different boards, and so on.

[0:23:56] The way the missile operated was you had a command link to the missile, you had a video link coming back which showed the video to the pilot or the weapons operator, and they would then use a joystick and move the camera, which sometimes was visual others IR, and so forth for different versions, and designate the target, and then direct the missile to hit the target. In later versions, the missile could be left, once it had acquired the target, it didn't need more commands from the launching aircraft. I think the maximum range was about 50 kilometers. Our task was to study the existing vulnerability of the command link and the video link, the return link, and once we had done that, come up with recommendations to improve the resistance to jamming. In the beginning, I didn't know it, Advanced Technology [ATL] was developing a compression system using… Fourier transforms and digitizing the video.

[0:26:10] Since we were classified, we didn't talk to teach other about… it was all for the Maverick. Anyway, my solution was keep the system simple, keep the analog video, because based on our tests, it wasn't really that bad that they could see them with pretty low signal to noise ratio, but the sync had to be improved. I recommended that instead of using the conventional horizontal-vertical sync, that we use a pseudorandom sequence which would automatically take care of both horizontal and vertical sync during the vertical blanking interval that way the sync was protected. That brought us many Db of anti-jam protection. Got a patent on that sync-protected system. Don't know what happened. Hughes was the prime contractor on the missile, they were also in the communications business and they may have change the links at some point. That covers the… most of the jamming.

[0:27:59] When the ECM group moved to Burlington, there was other work being done and I didn't go with them, so I merely switched to communications. But, of course, most of it was anti-jamming communications because I had the background for jamming and anti-jamming.

[0:28:29] Speaker 1: That was back here in Camden now?

[0:28:34] Edward: That was around 1962.

[0:28:36] Speaker 1: Okay.

[0:28:39] Edward: Then they moved it to Burlington.

[0:28:41] Speaker 1: Okay.

[0:28:45] Edward: Then the first communications job I worked on, it was in progress and pretty far along but still had some inputs, was called Project Pangloss.

[0:29:07] Speaker 1: What was that?

[0:29:08] Edward: Pangloss.

[0:29:09] Speaker 1: Pangloss.

[0:29:11] Edward: It was run by the Princeton Labs, but we were building hardware and the demonstration system, which operated with the VLF system on board submarines where they had long antennas trailing the submarine. We were providing very low rate anti-jam protected communication.

[0:29:57] We used the magnetic drum to store and receive signal and then do the correlation and finally print out a message at a few bits per second, but they were highly protected. Then in… it was 1962, we bid on a top secret communications system that came from the Marine Corp via the Navy. We won the job. First we had to set up a top secret facility for it. There was a small building on the roof of 10- building. It was outfitted with an anteroom where we had an armed guard and where we could have conferences with people who weren't cleared top secret, then a top secret are where we had offices and small conference room, big fancy safe, typewriter ribbons were locked up every night in the safe since the typewriter ribbons were classified. The hardware itself was secret and so other people within the building could build it, but they didn't know what it was for.

[**0:32:04]** They weren't involved in the operations analysis, that was top secret; in other words: What's the threat? What can we do about the threat? And so forth. Two of my engineers, John Allen and Jim Feller, wrote a secret Master's thesis on the hardware for the University of Pennsylvania. It so happened that their adviser, Dr. Berkowitz, was a consultant for RCA and had clearance. He worked summers in Moorestown. And so they got their Master's degree. Both of them did very well. Jim Feller became Vice President of… I don't know what the name of the company was at the time but it was Martin Marietta at that point. John Allen became staff engineer of the first division head in Camden and then division head in Moorestown; unfortunately he died a number of years ago. We had a very good crew.

[0:33:42] Speaker 1: Can you talk about that a little bit? What about your coworkers? What were they like?

[0:33:51] Edward: Well, we had some of the brightest engineers. I was part of hiring Jim Feller, I interviewed him when he came out of school, University of Michigan, and I told my boss, "We've got to get this guy" and we did; and he did well for himself and the company. John Allen was also very bright. At that time, we had [0:34:31 Ron Buskirk who left us but he found one of the papers we wrote together. A little bit later, Conrad Haber came in. So a lot of the engineers who worked for me did very well.

[0:34:56] Speaker 1: Okay.

[0:34:57] Edward: Now, talking about the top secret program, was called Venus. I won't go into any of the technical details; but one time, whenever I traveled with top secret material, had a briefcase with a chain and handcuff so nobody could grab it; so one time, I was invited to come down to Norfolk and brief one of the ship captains about coming technology to counter the threat. It was organized by an engineer from BuWeps at the time, maybe.

[0:36:00] Gave a presentation and he was really impressed and he said, "I want the boss to hear that." Who was the boss? I don't remember… Admiral something or other, head of the Atlantic fleet. So he walks us over to the other ship and as we approach, all the marines attention and blowing the whistle and so on.

It came to that point.

Yeah. That was an interesting experience. They had no idea about the threat and about what we're trying to do about it. Now, another time I was asked to give a presentation to NSA. I went to NSA, again with my brief case and the chain and handcuff. I gave them the presentation and I was 4:00 o'clock or 4:30, close to quitting time, and I'm ready to leave and they said, "No, you can't take top secret material out of this building." So how do I get out of here?" Well, we have to go up the chain and find someone who's authorized to sign for top secret material." Somebody had gone home already and eventually they found someone who was still there and who could sign off so the guard would let me out.

[0:38:05] So that was an interesting experience. I had visions of spending the night there.

[0:38:12] Speaker 1: Okay. So that was the 60s…?

[0:38:16] Edward: 62 to 64 era.

[0:38:23] Speaker 1: After that, you were in the communications group then? Was that…?

[0:38:28] Edward: Well this was also communications.

[0:38:31] Speaker 1: Oh okay.

[0:38:32] Edward: Yeah. Let me see if I have anything else listed in that. Okay, chronologically, that brings us to the, I mean, there were proposals and other things.

[0:39:14] Speaker 1: Uh-hmmm. Right.

[0:39:16] Edward: The in between. In fact, we won a job called Harpy. It was somewhat of a follow on to our top secret program, but it was a dual award. Magnavox got one contract and we got the contract. I was working on that and one day, I bumped into Sam Holt who at the time was… I knew him earlier from Data-Link and so on.

[0:40:02] We were selling transistor radios to the Japanese. Data-Link radios. He said, "Come to my office. I wanna talk to you." This was in '67, after the Apollo fire, which was January '67. He said NASA has a problem. Originally the configuration of the command module and the space module for rendezvous was that each would carry a rendezvous radar and a transponder so they could perform ranging from either side. Burlington was building… Massachusetts, the RCA Burlington, was building the rendezvous radar. Actually, Sam Holt was the program manager of the RCA portion of the lunar module electronics. The communications was done in Camden. The radar was done in Burlington. After, I don't know whether they eliminated the second radar, the redundant one, before or after the fire because it was 80 pounds and that took a lot of booster power. But after the fire, they insisted they have to have a redundant system of some sort, and they had mentioned that to Sam Holt in one of his travels to Houston.

[0:41:59] So he asked me to take a look at it, if there's any way to use the radios for ranging, they could get angle measurements with the Sextants. So I started looking into radios, I asked that measurements be taken of delays, through various parts of the radios. The delays were horrible. Delay variations from unit to unit were bad, and most of the delays were in the intermediate-frequency amplifiers and crystal filters were used for selectivity. I came up with a ranging system that allowed the use of the radios without any modification but it wasn't very accurate a thousand feet or whatever. I also came up with a configuration that was more like a hundred feet but it required that something had to be done before the IF filters. The RF amplifiers were wide enough in the radios; but as soon as you got to the IF, then you were into narrow bandwidth, which meant delay variation, time variation, range variation.

[0:43:57] The option was to either turn the local oscillator on and off, which required some small addition, or put the switch in the pad after the down converter before the IF and switch the signal with a reference new correlation at that point, and the resulting error signal would be low enough to pass through the intermediate-frequency amplifiers. We said, "Okay, let's put a presentation together. Let's go on down to Houston and give them the options." Making changes to the radios meant radios that had already been shipped had to be brought back. It was when the moon landing was in '69, some of the earth's orbits and rendezvous, and so it were earlier in '68, so we're talking in '67 the radios were already being installed or in place. We went down to the room, in Houston, and had a room full of people, and the spokesman was Frank Borman . He was tasked with the ranging and the rendezvous problem. I gave the presentation and it didn't take long he said, "I want a more accurate system. And how soon can you start?" And I think within a week we had authorization to spend up to a million or whatever until we could come up with a cost estimate… I mean, they were in a time bind. That's how we started with the program. The technical issue was… I may have lots of material that I can show you, I can leave some with you. The technical concept was that we had a reference signal which was sent… a ranging signal that was sent by the transmitter at the command module. The transmitter was wide band so it didn't distort the signal. The voice at that time was pulse-width modulation so the transmitter was on and off. It wasn't conventional amplitude modulation, to get the most efficiency out of the transistors. The pulse-width modulation started with a sawtooth. It was added to the voice and then clipped and you have a pulse-width modulated signal.

[0:48:00] It turned out we couldn't really use the pulse-width modulated signal; there was too much variation to get a good ranging signal. So we changed the frequency slightly to make the numbers come out. In those days, number conversions from one set to have things come out in hundreds of a nautical mile or so. Easiest thing was pick the right frequency. We used, I think it was 31.6 kHz square wave as the ranging signal. The technology that made it work was to do a correlation in the receiver and the wide band portion of the receiver, which was right after the mixer, before the signal went to the intermediate amplifier. So we were applying a reference signal to a switch with an early reference and a late reference. The switching rate between early and late was low enough by 5 kHz so it would go through the IF. It was an error signal now, it was not , no more, the actual ranging signal. The whole system used three tones.

[0:50:00] One of the tone was in the, I think by 3.9 kHz, that's well within the audio range. The second tone was 247 Hz to get unambiguous range but the other amplifiers weren't designed to handle that low frequency so I combined it with the middle tone, modulo 2 addition. So we had the low tone information there but it was still subcarrier, so it passed through the narrow band part.

[0:50:52] Speaker 1: What kind of accuracy did that give you?

[0:50:55] Edward: In the end, we wound up with a hundred feet rms.

[0:50:58] Speaker 1: Wow. Okay.

[0:51:00] Edward: And we had… we were talking about it but I don't think it was ever done. We measured every radio for delays through different portions of the radio. We could've done a little bit better by individually calibrating each radio or do a computer correction or something. The only problem was in those days, this was in the '60s, computers done by MIT and the programs and the memory were stored in cores and they were threaded, they weren't programmed, they were actually physically threaded with the program, so making a program change was a big deal.

[0:52:05] The computing power was such that it wasn't practical to make corrections. We picked frequencies that gave us the right nautical miles, in fact, hundreds of nautical miles. There was no conversion required.

[0:52:30] Speaker 1: We had heard that the system worked so well that it actually became preferred to the rendezvous radar. Is that correct?

[0:52:42] Edward: Yes, we had multiple modes. We had the acquisition mode and we had the operating mode. During the operating mode, we could handle voice at the same time, but it was clipped speech. It was not pulse-width modulated. We also had the third mode which was voice only, which was pulse-width modulation. Intelligibility was a little bit better than a clipped speech, but the next… after Apollo 17, the next NASA mission, where the system was used, was Skylab and it did not have a radar transponder, it only had the VHF ranging system.

[0:53:52] Speaker 1: That's pretty impressive.

[0:53:54] Edward: And it worked for all the Skylab missions.

[**0:53:57]** And then when NASA started talking with the Russians about doing a rendezvous with the Soyuz, They decided that the lightest and cheapest way to do it was to use the VHF ranging system and have the lunar module transceivers and the processor, which was called the range tone transfer assembly, not my choice. But it described what it did. The way it worked was that it actively tracked the fine tone, which was the… actually, the range determining signal, it turned around to lower frequencies. There was no processing of those. Delay variations were acceptable to just turn them around and accept…

[0:55:14] Speaker 1: So that system was actually…

[0:55:16] Edward: We had to tweak it a little bit once we got all the measurement numbers.

[0:55:22] Speaker 1: Did you have anything to do with the Apollo 13 incident?

[0:55:27] Edward: I was at the Cape watching the launch.

[0:55:30] Speaker 1: Wow.

[0:55:32] Edward: Walked away from there and drove away from the launch area and… Geeh! That was a nice launch. I've got pictures of it. Then later on in the radio, I heard that something went wrong but the crew was still all right.

[0:55:59] I'll tell you a few experiences during the Apollo program. Of course, I went to Houston many times, went to Cape Kennedy many times, went to the top of the vehicle assembly building and actually tapped on the command module that was…

[0:56:24] Speaker 1: Wow.

[0:56:25] Edward: You'd look down and people were about this big. Walked under the crawler. Huge thing with tons of tons stuff sitting on top of it. I was involved in the flight testing of the system. It was tested at White Sands on an airplane. Got great results there. Though it didn't go on the early flights because it wasn't ready, even though we got flight hardware in 14 months, which was unheard of, but you know: All stops were out. Whatever people you needed, overtime you needed, get it built, get it to work, get it installed.

[0:57:42] Speaker 1: So through all of this, how did you feel that the RCA management looked on your work?

[0:57:54] Edward: I was awarded the Sarnoff award for outstanding engineering.

[0:57:56] Speaker: Oh wow!

[0:57:57] Edward: for the VHF ranging system. I have pictures of Borman visiting the plant, looking at the equipment. It was a great time.

[0:58:21] Speaker 1: How did your supervisors treat you?

[0:58:31] Edward: Very well. Unfortunately, the best supervisor I had left RCA just about the time that we got started on the VHF ranging program. Because I was working on the Navy communications program called Harpy, which was a spread-spectrum system. And he was involved with Dr. Pritchard at Fort Monmouth.

[0:59:26] Speaker 1: What was his name?

[0:59:27] Edward: He was at RCA at one time…

[0:59:30] Speaker 1: Your supervisor?

[0:59:31] Edward: Bert Glaser. And he left just about… He may have written up the recommendation. I was one of the people involved in it for the Sarnoff award. He went on to Magnavox, became the vice president there. They were…

[1:00:05] Speaker 1: You had quite a career at RCA. How would you sum up RCA? What was it like to you?

[1:00:25] Edward: RCA was in the forefront of technology. I think they went downhill when they got into the carpets and banquet foods and other things that had nothing to do with the core technology. I guess they owned CIT for a while.

[1:00:53] Speaker 1: So you've…

[1:00:55] Edward: I'll get to some other topics where I was very disappointed.

[1:01:00] Speaker 1: Okay. What would you say was the best thing about working for RCA?

[1:01:13] Edward: I think the opportunities of working on great technology.

[1:01:27] Speaker 1: What about the worst thing?

[1:01:32] Edward: The worst thing was that they were not interested in pursuing small things. I can talk about that now…

[1:01:53] Speaker 1: Okay.

[1:01:54] Edward: Their… we can talk about another NASA program and then go to spinoffs from VHF ranging system.

[1:02:10] Speaker 1: Okay.

[1:02:16] Edward: NASA was coming out with a number of RFQs for experiments, which were done on the later missions. We bid on one that Raytheon had worked on before and they obviously won it. But then there was a second one, technology program, which was called the Lunar Sounder and, again, Sam Holt said, "This is a tough job," and he's spoken to NASA and they feel we can do it. So the Lunar Sounder went on Apollo 17. It was installed on the command module, service module, and it was a side-looking radar, coherent synthetic aperture radar, which mapped the moon. the command module was circling the moon while all the other stuff was going on the surface of the moon.

[1:03:59] The unit transmitted on three frequencies: 5MHz, 15MHz, and 150 MHz. And the low frequencies were designed to penetrate down to several kilometers below the surface of the moon. They were looking for water, which wasn't there. But they found things at 1.4 km. Different plates and surfaces and so on. The higher frequency, at 150 MHz, was mostly intended for surface features. I've seen some IEEE articles where they compared optical pictures with cameras and the radar images, and the advantages of the radar images was there were no shadows, while using the sun's illumination, you had shadows. Okay, so what was the problem with the Lunar Sounder? The transmitter was straightforward and the receiver was straightforward, except for one parameter. The system consisted of the radar, a set of antennas, and a film recorder which had a 10-hour capacity; it was made by Goodyear in Arizona, Phoenix.

[1:06:01] And digital technology couldn't record that kind of information, even tapes were too bulky. Film was the only medium that could handle all the data that was coming back, and the film recorder was brought back. Initially, it was processed at the university of Michigan where they used optical processing, optical correlators. I went up there and they showed me reconnaissance pictures from high altitude and you could see… you could almost read the street signs. And they said, "We can't show you the really classified stuff." Anyway, the RFQ went to Camden because we were in the space business. It went to Moorestown because they were involved in the… they had done antennas for the Apollo program and also for the Lunar Rover, this umbrella type antenna. They decided that the spec was impossible to meet. It required a -65 dB side lobe level with cosine weighting. And they said, "Any of the pulse compression we've done ends about 40 dB because that's the limit of pulse compression delay lines, which was state of the art."

[1:08:13] Speaker 1: Did Camden decide to bid on it?

[1:08:18] Edward: Camden asked me, "You think you can meet the requirement?" I said, "Well, I'm not sure, but the first problem is we've got to have a way to measure it." And my original proposal was to build a sweep circuit which did the frequency modulation of the radar, sweeping it, which was corrected over a number of points to make sure it was linear over the range. The next issue was, “How do you test it?” I came up with a technique where you use the signal and correlated against itself and, if there’re any distortions, they would show up. And how do you correlate the signal against itself? You put in a delay of one signal and you must take the output of the transmitter and then in a test set, use the same signal to delay it and look at the difference and you can look at it on the scope, and I have pictures that show it.

[1:10:07] Our management was kind of hesitant, but we had an approach. I said, “You know. Let’s see if we can borrow a radar engineer with pulse compression background.” And we’ve got… There were just a few people in Moorestown that had extensive pulse compression experience and we’ve got one of them, and he helped with the proposal. A radar book had just come out the part of pulse compression radar was written by George Stevens in Moorestown. So we had access to it. So right people who had background in pulse compression…

[1:11:16] Speaker 1: Did we win that bid?

[1:11:18] Edward: We won the bid. As we started to work the problem, and we had a test method, it turned out we could build the sweep that was linear enough that we didn’t have to use the corrections. Originally, the film was processed by the University of Michigan.

[1:11:57] Then as the digital technology improved. It was Jet Propulsion Lab. We started to use digital processing, and that allowed them to measure side lobes and correct for the side lobes. The side lobe problem was just when you’re looking to the surface of the moon and then down below, you get a lot of reflections from areas you’re not looking for, like the surface. So if the side lobes are high, you’re going to get a lot of returns from the wrong levels. So that flew on Apollo 17, it was very successful. There’s such a database, they still haven’t processed it all.

[1:13:09] Speaker 1: After that, you…?

[1:13:12] Edward: Interesting aside, a few months ago, I got an email from a guy name Reese Morgan. It didn’t ring a bell. It said, “Are you the Ed Nossen who worked on the Lunar Sounder? The CESAR I sent an email back and said, “Yes, I worked on it.” Gave him a little bit of a background that the radar people didn’t want to touch it and I was hoping to take a chance.

[1:13:57] We chatted back and forth and finally he said, “Okay. Here’s the story. My father worked with you at Rockwell, they were doing the command module. And in his diary he mentioned you many times.” And also when the program was over and Rockwell had a family store, there was serial number 1 of the CESAR and they were taking bids from employees, he put in a bid of $500 and he got serial number 1. And he said after his father passed away, he inherited a lot of space goodies he said that was one of them. He wants to interview me too.

[1:15:16] Speaker 1: Over your career you developed about 35 patents.

[1:15:22] Edward: Right.

[1:15:25] Speaker: It would make you one of the superstars at RCA.

[1:15:29] Edward: I got a bunch of plaques. Interesting thing was RCA didn't want to file a patent for the VHF ranging system. They told me there was a conflict, someone in NASA claimed "Oh yeah! I come up with that same idea."

[1:16:02] And they said, "Okay. Keep our hands off this." Once the Apollo program was over, what other business is there? So the patent department decided not to do anything, which is okay because I got them to file later on different versions of it.

[1:16:28] Speaker 1: Oh okay.

[1:16:30] Edward: One of the things, I don't think I mentioned that, when I built the noise filter for the servo system, I had wide bandwidth for large error signals and a narrow bandwidth for small error signals, I put in a patent disclosure. The patent department said, "Nah, we're not going to file." They weren't keen on filing for defense inventions; they were looking for commercial at the time. Later on they changed their mind. But the interesting thing was Dolby came out with the noise reduction system. I read the Dolby patent and said, "Geeh! Sounds like mine." Told the patent department, "Hey! I was there first." And they checked with Indianapolis where they were building stereo systems and so on for commercial use and they said, "Well, at the moment they're not paying Dolby labs.

[1:17:58] But if it comes to that, we'll bring it up and say 'Hey, maybe your patent isn't valid because they had published it as a technote, not as a patent.'" I think the difference between not paying Dolby, and they could've collected from Dolby and others, it's a big difference if it had been. There was another situation where I came up with an idea, I don't remember exactly which it was, but they didn't file. And about seven years later, I came across the application and told them "You know, I still think that's a good idea. Why don't you file them?" and they said, "Okay. We'll file it." And guess what? IBM had filed similar thing during the period that they were holding off.

[1:19:25] Speaker 1: As far as wrapping this up, how would you describe your experience? Your employment at RCA? Certainly, you had more than just a job here.

[1:19:39] Edward: Oh yeah. Well I have many more things I'd like to talk about. First of all, the Apollo ranging system, everybody acknowledged that, "Hey, it was an interesting technology and is there an application elsewhere for it?" So the Apollo program, the radios were full-duplex radios and most of the military radios, tactical radios and so on, were half-duplex. You talk and you listen. We went looking for an application about the Apollo system and talking with Air Force and other services. We came across a serious problem that they've had in Vietnam. When a pilot was down, he had a survival radio. It was a radio with a couple of fixed frequencies and a beacon. You could turn the beacon on, come find me. Well, very often, the enemy got there first. So what they were looking for was something that's secure. That doesn't send out a signal and keep it up. It was the same as the beacons they put on airplanes.

[1:21:57] An airplane went down and it was on land and the beacon would go off. I started thinking about, first of all, the half-duplex issue. You transmit a signal and some time later, that signal arrives and the timing depends on how stable the oscillators are, time references, how you're searching with an airplane, it's moving. We needed some technology that was different from conventional analog trying too loose, and so on. ATL had come up with a synthesizer, which we called the arithmetic synthesizer. In fact, Jay Butler got a patent on it. It basically was… you added a number and it was an increasing number, so we had essentially created a sweep and you could count up, count down, generate a signal, and the stability was based strictly on the clock that drove it.

[1:24:08] With that, it was possible to remember frequency, time, and if you had… they have great information. They could even include that if it was the result of airplane motion, and so forth. We finally had a system that looked like it would work and we convinced the Air Force at Wright Field that they would go out and procure a demonstration system. We got the RFQ and RCA, the marketing, and others looked at it and they decided, "Nah, we don't want to be in that business. We're not going to bid." I was pretty upset. We got in touch with Cubic, San Diego. They had done some search equipment for downed airmen, but they were just looking for a signal and direction.

[1:26:04] They had, obviously, had no range. But we teamed up with them and got our management to agree to go along as a subcontractor. We won the job, the team won the job. We built the airborne interrogator, which was looked like three circuit board set fit into the Cubic equipment, and we built a very small transponder module which had the tracking circuits and all of those things. We did some other things. For security reasons, we used pseudorandom sequences which had a period equivalent to the 247 Hz low frequency tone, but now it was the duration of its sequence, so that gave us several hundred miles of unambiguous range. Since the radio that was being built and targeted for this was the PRC 112; at the time, it was built by Motorola. They introduced the correlation circuitry in the radio and we would drive that.

[1:27:59] We also made another change, since these were really low powered radios, we didn't want to use an on-off type modulation. So we switched to phase modulation. I mean it had the amplitude modulation for normal voice but for our application, we used the combination in it: amplitude and phase modulation; and it made it more efficient. Instead of being an afterthought like the Apollo program now, it was designed from the start. We built the little modules and in '92, no… '82 we ran tests with the Motorola radios and we also tested with Tadiran radios. Tadiran was also in the search and rescue business. It worked successfully with the Tadiran radio and with the Motorola radio. Since then, the PRC 112 went through iterations from A to G since the original module was built in '82 with custom LSI chips done in Summerville.

[1:30:03] Well, the technology wasn't available anymore and they were forced to switch to all software implemented modules. Along the way, they added GPS and there were like 31,000 of them built and RCA walked away from it. I have pictures of our module, Tadiran module, sitting in a Tadiran radio. I believe that they were still getting the chips from RCA until that was over. The services came out with a new rescue survival radio. By the way, every astronaut carried a PRC 112 because if the mission was aborted early enough, they could parachute out and wind up at a down range in the ocean and they used those. In fact, I have an article where they simulated the search and rescue of astronauts 40 miles of the mainland. The follow on system was… the Motorola sold their division to General Dynamics and they built the ones with the processor controlled option.

[1:32:05] But it was the same DME waveform that we had used earlier. The follow on radio was built by Boeing and it had all kinds of bells and whistles. Since it had GPS, they were suggesting, or someone said, "Gee, we don't need that DME function anymore." And the Military said, "Now wait a minute. What if GPS is not available? What if it's denied? Jammed? Whatever. We want to keep it in there." So at this point, there are over 80,000 radios that have that function in it.

[1:32:57] Speaker 1: Wow. It's amazing. We got, I think… Why don't we take a little break?

[1:33:06] Edward: Let me just mention one thing. I did get a patent on the rescue radio version the half-duplex with the phase modulation and so on. I also found out that there is a company which has offices in this country and sells or leases equipment which uses a system developed by Tadiran for the rescue of downed pilots; it's what it says in their opening statement on the literature. Well, Tadiran got the technology from us.

[1:33:57] Speaker 1: From us?

[1:34:00] Edward: What they used it for was to keep track of people, cars, boats, and so on. Again, some place where GPS might not work. They claim to have lots of users.

[1:34:25] Speaker 1: I imagine. Yeah.

[1:34:30] Edward: And they apparently installed… it's a competing system to LoJack. And they've installed a number of towers to cover a given area.

[1:34:46] Speaker 1: All on that one invention.

[1:34:51] Edward: And RCA dropped the ball.

[1:34:57] Speaker 1: Okay, Ed, while we are going to pick up this interview when you were telling us about the post Apollo things.

[1:35:09] Edward: Right. In the early '70s, which was obviously after the Apollo program was over, we worked with the group in Moorestown called Seer systems engineering group, and they had gotten a contract to study remotely piloted vehicles.

[1:35:52] In Camden, we studied the communications requirements and configured a communications system to handle a large number of such vehicles that were involved in performing reconnaissance, which meant high data rates, and we had an IR&D program and we built an breadboard system working at SHF. The antenna group in Moorestown developed a phased array that would fit on a remotely piloted vehicle so that it could act as an airborne satellite repeater so that many RPVs could send signals to it and it would send it to a control center. As a result of the IR&D work we did, we got a contract, one of two contracts, with the Air Force Wright-Patterson. The other company was Sperry in Salt Lake City. We came up with a detailed design and we wrote a specification for hardware development, so did the other contractor, and there would be a down selection to a single contractor to go ahead with hardware development.

[1:38:00] Through various sources, I won't say how, we found out that it essentially was our specification that would've been put out on the street. Unfortunately, The Pentagon withdrew the money and we learned that the pilots were against it at the time. They didn't like unmanned vehicles because they would lose their flight pay. The interesting thing is we applied for spectrum for this system. Years later, we were notified that our request for a spectrum in the SHF band had been granted, although the program didn't go anywhere at the time. We were ahead of our time, I guess, as far as RPVs went and name changed over the years but now the drones, unmanned vehicles and so forth. Going ahead to 1977, especially October, or leading up to that, was a very busy time for me. It turned out I had six conference papers with my name on it.

[1:39:48] Speaker 1: Wow.

[1:39:54] Edward: I couldn't even go to one of the conferences. Conrad Haber reminded me that I send him.

[1:40:03] He was one of the co-authors. It was his first time at a conference as a speaker, but he got the experience.

[1:40:15] Speaker 1: Yeah, he mentioned that that was quite a traumatic experience for him.

[1:40:23] Edward: The reason there were so many was that Robert Dixon, who wrote a book on spread-spectrum, he was an acquaintance I met at a conferences and other places, he called me one day and he said, "I'm running this conference and the papers are very slow in coming in, do you have any?" And I said, "Well, I have something but I can send you some abstracts for other things that I could write about." I sent them in and he called back and said, "I'll take all three." One of them was about the Apollo VHF ranging so I had all the material there. But the other interesting thing that happened, around the same time, the government of Israel invited RCA to send several representatives to Israel and they would be chauffeured around for a week and visit many companies and also military establishments.

[1:41:54] I was selected to represent the communications division. Wendell Anderson was the other and the third was Bob Trachtenberg, and they represented advance technology M&SR. I decided to combine it with a sightseeing trip as it this was first time. I took my wife, we flew to Paris where she had relatives and she stayed there. I flew on to Israel. We were driven around, spoke to CEOs at different companies like Tadiran, Elbit, Raphael government organization and others. We had slides of a lot of the unclassified material we could show. We met with some of the intelligence people, showed them what we had. With the Air Force, on one evening, we met with an Air Force General and his staff. After three hours or so of presentations and talking, he finally said, “Thank you very much, but don’t tell any Israeli company how much time you’ve got, because I gave you a lot more time than I give to locals.”

[1:43:57] After we were done with the business, my wife came over and then we took a tour with a tour bus that took us all over Israel and it was a worthwhile trip. As it turned out, also for business. For instance, at Elbit, which is a computer company, I asked them, “Where are your costumers?” And then they had a whole bunch of names including Egypt, Saudi Arabia… I thought there was a ban on exporting to Arab countries. Well we don’t show anything in Hebrew and we send it through a third party country and everybody is happy. RCA was building equipment, RCA was also blacklisted after the ’73 war. In Burlington, they were building emergency landing facilities, shelters with equipment, and so on. They could not show RCA on there when they shipped it to an Arab country, just a US government number. After the trip to Israel, where…

[1:46:01] By the way, I also was met with the Tadiran people which figured in the survival radio business. We got a request for proposal from the Israeli government for development and installation of a large surveillance system involving airborne and ground facilities and ground-to-ground connections and so forth. We won the job, which was in the hundreds of millions. We set up a separate facility for two reasons, in the East Gate on Gaithers Drive, we had Israeli engineers coming over to participate in the development and also, for security reasons, was kept separate. The hardware was built in Camden, but all system work and customer interactions were done in East Gate.

[1:47:57] I was responsible for the communication and support system, both ground based and airborne. I had an Israeli subcontractor. We provided stable platform for the airborne segment and had uplinks, downlinks and so forth and then ground links to pass the information to central site. I made a number of trips to Israel to interface with my subcontract there. We had a problem with the stabilization system. We used a Singer gyro stabilized system and they were scaling it from another application and it turned out it didn’t scale that well. There was a lot of investigation and finally, I decided to take a look at it, and my conclusion, “You need more gain for the Gyro system signals to make this bring it up out of the noise.” At that time, I was pulled off the program.

[1:50:02] Most of the stuff had already been built. I was put on the mobile ICBM program that we had just the won from Boeing. We were just in the concept phase coming up with different options. We were looking at things that were really new to us like meteor burst communication, near vertical incidence, HF communication. In addition to frequency hopping for protection, we started a HF modem for a near vertical incidence communication. Then it turned out when RFQ came out, I don't remember exactly the agency, but we won the job. We built the modem… I had configured and we had two options, 64 alphabet modem with either FSK or CSK code division…

[1:52:01] Pseudo-noise. We tested that successfully, outfitted a truck with, a small truck, with the necessary test equipment and the modem and the HF radio, and drove to different locations. One time I was in the RCA office in Washington and our marketing guy brought in his counterpart from Harris. Harris was always our arch competitor in the satellite business and so on. We were talking and finally he said, "How did you win that modem job?" I said, "Well, we had some good technology, some good ideas." He said, "We wrote the specs for it. We were supposed to get it." I said, "What? We probably had better ideas." I did a lot of commuting to Seattle, to Boeing, during the mobile ICBM job. We had just signed a contract for full-scale development.

[1:53:55] It was over $100 million and we were rejoicing indeed, won another big one, and then the Berlin wall fell, and contract was canceled immediately. Okay… We're in a different phase now. When we had the contract with the government of Israel, like I said we went to Israel. In fact, our first major design review was held in the Tel Aviv Hilton Hotel for two weeks. They cleared the floor, swept it for bugs, brought in files for secret documents, posted guards, and we slept on a different floor, ate on a different floor, and had our business there. It turned out to be successful. I was looking out of my hotel window in the morning and I saw all these windsurfers on the Mediterranean. Finally, I just said, "I got to try that." I was a sailor, I had a small boat, but my brother had a bigger one. I went out there when we had an afternoon off and started on the simulator.

[1:55:56] Once I got back to the United States, I took it up seriously and I owned a couple of boards. After the ICBM program was canceled, I went back to business as normal. We heard about a procurement from ESD for a portable SHF satellite terminal, really portable like carried in a backpack. There was an article by Mitre in Milcom '89 or so and I looked at it and it described the protocol and it's not going to work. So we went up to Mitre and talked about it. We really didn't have much to offer, this was like January of '90. I was just rereading a report that said we went back in April and I gave the presentation. I had a fully fleshed out system with protocol and they were amazed, it came from nowhere.

[1:58:00] In three months, what turned out to be very similar to what they had done in-house, they realized that the one they published before was unworkable. There was no throughput. So we had all our view graphs marked the "company private" and so on, and they were wondering why we did that

	and we mentioned, “Well, we might want to file for a patent.” They were a little bit sensitive but they were sure that nothing had leaked, that we had come up with independently. After we began, we won an award and Harris won an award. We each built a terminal and it used the reset concept where you have small terminals communicating through a satellite and then there's a very large control terminal so you get a lot of power going through the satellite to the small antennas, and by the same token, small amount of power goes up to the satellite, received by this big control terminal.
[2:00:13]	The program was very successful. It was tested in a number of places. This was the time when I officially retired and so I didn’t stay that close to it. But the most interesting part was after the US tests were done, they wanted to include the United Kingdom, and both the Harrison and the GE unit went over there, and we tested first, from what I heard, automatically acquired… entered satellite coordinates or so and found the satellite, acquired it, tracked it, communicated, and Harris couldn’t acquire the satellite. And they said, “Can you tell us where it is?” That’s about the story. I have a… Oh it turned out that there is the datasheet on it. Interesting thing is I found two datasheets. One is marked GE Aerospace and the other one is marked Martin Marietta.
[2:01:58] Speaker 1:	Right, during the transition.
[2:02:00] Edward:	That was the period when this was completed and tested. Here’s a picture of units… and units in the field. I found a conference paper written by the project engineer at the… yeah, it was a military guy… he commented that the RCA unit had much lower side lobes and therefore was better suited for low probability of intercept. I don't know what happened after that as far as procurement. And of course, I got a patent on the protocol system design. That was like my last effort at…
[2:03:41] Speaker 1:	All 35 patents, right?
[2:03:44] Edward:	Yes.
[2:03:44] Speaker 1:	That's pretty remarkable.
[2:03:47] Edward:	I have to tell you a story about one patent.
[2:03:51]	I came up with a design, tell you in a moment what it was, and sent a disclosure in to the patent department and they decided to file it. And the question that came back, “How come you are disclosing something that's not in your area of business?” You know, military electronics or something. I told them, “Well, one of my hobbies since I was in system engineering, I still liked to dabble in circuit technology, designing circuits, and playing with transistors, whatever, ICs…” and I had always an interest in test equipment since I've worked in television repair early on, and so I found a connection in Harrison where they built the RCA test equipment and they had equipment that was out and came back because the case was damaged or something, they couldn’t sell it, and they would make it available to employees at half of manufacturing cost.

[2:05:59] So I got tempted and one of the first units I bought was the Solid State Master Voltohmist Big Meter. I used it for various purposes and I got disgusted with it. I didn't like the way the controls worked. I mean, switch from positive to negative; if the meter was up, then the needle would go down; so I used the systems engineering approach, "Okay here's what I want to achieve. Here's what it's doing now and how can I get around it?" I came up with a circuit modification including using an op-amp and modified the circuit board, and it worked like a charm. That's it. Let's say it's admiral. By that time of course, RCA was going out of the test equipment business. Discussions with several of our attorneys, patent attorneys, said "It doesn't matter. We make deals. A hundred patents of ours versus a hundred patents of IBM. It's a package deal." So the more we have, the better off.

[2:07:46] Speaker 1: Interesting.

[2:07:47] Edward: It issued.

[2:07:52] Speaker 1: Yeah. That certainly is a remarkable career that you've had. As I mentioned, several of our… other people that we interviewed had mentioned you as a mentor or a contributor or something that advanced the electronics or advanced the Science.

[2:08:23] Edward: Oh again, there's one thing. We spoke about frequency hopping briefly. As part of the RPV program, we had done it for SHF. One of the products that RCA made for years in Cambridge, Ohio were Manpack radios and the POC-77, I think it was. The Army was ready to go out for a new generation under a program called the SINGARS and they wanted AJ protection. So we built a couple of models with our design and in fact I remember we gave a paper at the classified conference and actually demonstrated the radio's acquisition of codes and communication and so forth. We thought we were way ahead of the industry.

[2:09:56] When the procurement came out, RCA didn't want to bid. One of the stipulations in the procurement was that they wanted NATO participation. Instead of not bidding, it was decided to team up with the British company, Racal. So they came over here and we wrote the proposal, and we lost. We went to the debriefing, there was a lot of gobbledygook. Not a clear story. Years later, I met one of the guys who was on the evaluation board or so, and we were talking, he said, "Off the records, you guys won the technical competition hands down, but our management did not want to deal with a foreign prime contractor. If you had bid prime with them, so you would've won." So it was a consolation that the technical aspects were way up there.

[2:11:47] Speaker 1: Yeah and that seems to be a very common story with RCA so…

[2:11:55] Edward: They didn't want to bid on other programs where we had really set the stage for it.

[END OF TRANSCRIPT]