press for Sarnoff had been invited to lunch at the White House with President Truman that very day and it seemed obvious that Truman would produce the appropriate shoulder decorations. DS went off to lunch in high spirits and returned in the afternoon anything but elated. Truman had asked DS to be National Chairman of the 1951 Red Cross Campaign to take place in March of 1951.

Early in November, plans were made in New York for extensive demonstrations in Washington during the month of December. DS came to Washington to assure himself that it was proper to proceed with elaborate shows. Vice presidents arrived in large numbers in order to agree with the General should he make any profound statements. Most of the entourage arrived with DS the evening of November 6 and took rooms at the Carlton Hotel. On the morning of November 7, I encountered Bob Shelby, Chief Engineer of NBC, at breakfast at the Wardman Park Hotel where I was staying. I expressed surprise that he had left the assemblage at the Carlton and had strayed into our plebian surroundings.

He replied, "I just wanted to be someplace where I could say 'Yeh' instead of 'Yes, Sir.' "

At midmorning, we gathered in the NBC studio in the Trans Lux Building and viewed some very poor color pictures. The poor performance was due entirely to interference by a great number of unskilled but uninhibited executives who had given very curious orders at random and had overawed the technical staff when I was not present. DS was subjected to a number of very silly statements concerning the reasons for the mediocre performance and I made some statements which displeased some of the officers of the company since I contradicted more than a few of them. In fact, one vice president later told me that he would not have made his remarks if he had known I was going to speak out as I did. As a result of my outrageous attitude, I regained control of the messy situation and we soon restored our operations to a respectable state.

Since the November seventh affair had been staged to see if it was safe to go ahead with the December demonstrations, I was fascinated by learning, a few days later, that some busybody in New York had already dispatched, before November 7, the telegraphic invitations for the December events.

The demonstrations began December 5 with the press in the morning and with over eight hundred representatives of patent licensees in the afternoon. The demonstrations continued for two weeks with audiences composed of broadcasters, consulting engineers, attorneys, manufacturers and government employees. The pictures were excellent, we were proud of our progress but my colleagues and I longed for a chance to stop demonstrations and take some giant steps toward a total system.

In the meantime, W. R. G. Baker had appointed an Ad Hoc Committee of the NTSC to make an appraisal of the state of the art. On November 20, he designated David Smith of Philco as Chairman. The other members were T. T. Goldsmith of DuMont Laboratories, I. J. Kaar of General Electric, and A. V. Loughren of Hazeltine with Elmer Engstrom as the RCA member. R. M. Bowie of Sylvania joined the committee six weeks later. This committee examined the historical background of the art as well as the color television systems proposed to the FCC in the recent hearings. It also visited the laboratories of its several members and witnessed a number of demonstrations.

After months of double talk to avoid giving RCA credit for its massive effort and incredible developments, the committee came forth with a statement to the effect that color be added to the existing broadcast service by utilizing the black-and-white standards to transmit all the necessary information concerning brightness and by adding the necessary chromatic information to color the picture on a subcarrier transmitted simultaneously with the brightness signal and contained within the video band. In addition, to detect this subcarrier information, reference or color-synchronism information was to be added to the black-and-white synchronism signal during an interval of

time available for this purpose in the existing standards. The committee's report carefully avoided the fact that this sought-after solution was the same that RCA had described for many months, but Elmer Engstrom had to go along with this thinly disguised joke in order to avoid destroying the fragile confederation. The report also went on to point out the need for further and detailed testing by the industry to determine suitable numerical values for the standards.

With the report of the Ad Hoc Committee in hand, Baker established and organized, on June 18, 1951, what has come to be called the second NTSC although by counting the events of January, 1950, this latest effort could be designated the third NTSC. This time, the vice chairmen of the National Television System Committee were David Smith, Donald Fink and Elmer Engstrom.

While the Radio Television Manufacturers Association took the initiative in establishing the NTSC, RTMA exercised no authority over the operations of the NTSC but did underwrite the cost of reproducing minutes of meetings and reports. The membership of the second NTSC eventually included senior engineers from twenty-nine organizations as well as a number of individuals who could contribute to the work.

Eleven study panels were established, each with an assigned mission. The companies which participated were each allowed to appoint a member and an alternate to any or all panels. We chose to have RCA represented on every panel. I was the RCA member on Panel 13, a key panel which had the task of developing the field-test specifications and the final proposed standards if such a proposal were to be made. This panel would generate proposals for tests and would also draw upon the other panels for information and inspiration. I was also a member of Panel 12 which was assigned the preparation of monographs for publication and for distribution to the industry in order to disseminate new concepts as quickly as possible.

Many times during the progress of the NTSC, I was aware that many people assumed I was getting direction

from Sarnoff and that I was bound by him to protect the patent position of RCA. Actually, my directive from the General on how to behave was very brief—"Be sure we end up with a system which works."

The various panels of the NTSC immediately began a series of lengthy meetings and discussions. Whenever a controversial point arose, one or more of the participants arranged a laboratory test which was usually viewed by the panel members so we did a bit of traveling to General Electric Laboratories at Syracuse, to Philco Laboratories near Philadelphia, to RCA Laboratories in Princeton and to a number of other locations.

Earlier in the year, my associates at RCA Laboratories had found a method of reducing the effects of color cross-talk and timing errors in our system. This method, called Color Phase Alternation or CPA, seemed a very simple and delightful solution. Prior to this development, we had taken samples of the three primary colors in sequence, line after line and field after field, in the order Red, Green, Blue, Red, Green, Blue, etc. In practicing CPA, one field (the odd-numbered lines) was sampled as above, R, G, B, R, G, B, etc. In scanning the next field of even-numbered lines, the sampling was R, B, G, R, B, G, etc. This alternation continuing field by field required a bit of extra circuitry at both the studio and the receiver in order to let the receiver know what was happening at the studio. The effect on the eyes of the observer was to average out the errors and we were enchanted by the results. Our confidence was increased when Hazeltine Laboratories revealed that they had achieved the same result by the same method which they called Oscillating Color Sequence or OCS.

The various panels reached agreement on signal specifications to be tested in the field and Baker, on November 26, 1951, was able to release for publication NTSC Color Field Test Specifications. Since the field-sequential system adopted by the FCC was the only method of transmitting color permitted for commercial broadcasting, it was necessary to obtain special temporary authorization for field testing at odd times of the day or night. Under these

restrictions, NBC's Station WNBT in New York became KE2XJV on Channel 4 while WNBW became KG2XDE. Philco in Philadelphia, Zenith in Chicago, General Electric in Syracuse and a number of other participants made arrangements to use their respective broadcast facilities for field testing.

The field test specifications called for a brightness signal formed to yield constant-luminance reception, a color subcarrier proportioned somewhat differently than our previous practice, a synchronizing burst on the back of the horizontal synchronizing signal and the use of Color Phase Alternation by fields. I related to Panel 13 my reasons for reducing the frequency of the color subcarrier in November, 1949, and stated how much better our performance had been ever since then by using a frequency of 3,583,125 cycles per second. In spite of my admonishments, the panel members felt the need of a higher frequency and chose a value of 3,898,125 cycles per second, a value which was 495 times one-half the line-scanning frequency and that was the value specified for field testing.

Field testing went on at a great pace at many locations. Very many nights were spent by panel members and members of duly appointed subcommittees, observing transmissions of color signals of a wide variety. While all the participants in the NTSC work cooperated wholeheartedly, the brunt of the work fell on RCA and NBC because of the vast amount of color equipment installed at the NBC studios in New York. In July, 1952, we conducted experiments in Princeton in which we used a variety of black-and-white receivers from a number of manufacturers to test for compatibility by means of broadcasts of color signals from the NBC transmitter in New York. These tests, viewed by a selected audience, revealed the need for modifying slightly the manner in which the burst was added to the total signal. At the same time, NBC made appropriate announcements to solicit comments from any home viewers who chanced to be watching the broadcasts. Nine hundred and forty-seven responses resulted. This information was analyzed by Opinion

Research Corporation of Princeton and confirmed our results obtained at RCA Laboratories. We immediately conveyed our conclusions to the NTSC panels and our recommendations were accepted by the members.

As we continued to experiment with reception of color television pictures on our own color receivers and on those built by other members of the NTSC, I had the same urge to reduce the frequency of the subcarrier just as I had been prompted to do for the November, 1949, demonstration. Finally one afternoon late in August, Wendell Morrison and I found we were in agreement on this subject and we quickly sketched out the procedures necessary to carry out a test on a scale large enough to convince the panels of the NTSC. We knew that lowering the frequency of the subcarrier would produce more stable results on color receivers but that a lower frequency would produce coarser and more visible dots on black-and-white receivers when color signals were present. But how much would the viewer be troubled? To answer this question would require a field test on a grand scale.

Before the afternoon was over, we presented our proposal to Engstrom and Jolliffe. After an hour of discussion, they agreed that we should proceed. Wendell Morrison and his associates sketched up the necessary apparatus and placed orders on the model shop. The receiver people were alerted to what was planned so the receivers would be ready for the test and the NBC engineers were likewise informed. NBC program people were also enlisted to provide appropriate programs that would ensure an audience.

The over-the-air broadcasts started on September 16 and continued for eight days. The color-subcarrier frequencies used were 3.58 megacycles, 3.75 megacycles and 3.89 megacycles. These three subcarrier frequencies are given as approximate values. The exact values were, in the same order, 455 times one-half the horizontal line-scanning frequency, 475 times one-half the line frequency and 495 times one-half the line frequency. Each fifteen-minute test program was divided into three five-minute segments.

During successive segments a different subcarrier frequency was used or, in several cases as a further basis of comparison, a black-and-white picture was broadcast.

At RCA Laboratories, nine black-and-white receivers of differing makes were arranged and observers were selected from the nontechnical employees of RCA Laboratories. NBC announcers also made appropriate remarks to secure responses from the viewing audience. Many hundreds of responses resulted each day and revealed that a surprisingly large number of medical doctors in New York City looked at television in the middle of the morning. The results of these tests showed no marked preferences for particular conditions except that Kukla, Fran and Ollie seemed to carry more weight than did our selection of subcarrier. The responses from the selected viewers at RCA Laboratories as well as the letters and postcards received from viewers were again turned over to Opinion Research Corporation for analysis and for a report bound in an impressive cover. Since my secretary had already counted all the messages and tabulated the results, we did not need the services of Opinion Research Corporation but we realized that their participation gave us an air of respectability and perhaps a better standing when we next confronted the FCC. In any event, Morrison and I felt all the work which had gone into the project had been worthwhile for now we could continue to use the 3.6 megacycles subcarrier with no fear of affecting compatibility.

Several RCA executives in New York had experimental color television receivers in their offices, all operating on 3.9 megacycles. I had neglected to alert these people and explain the tests. When the program shifted to the new subcarriers, these receivers did not function. In fact, they failed to perform at all. The viewers, nontechnical executives, felt duty-bound to explain to DS that only one condition was even possible. This meant profuse ripples and more educational work for me.

Perhaps to justify the fee, Opinion Research took an inordinate amount of time to fiddle with the postcards and

to write a report. The report finally issued on November 10 and I immediately sent copies off to the NTSC. I had of course given Panel 13 a story on the test results long before this date. As a consequence, Panel 13 accepted the lower value of 3.58 megacycles (455 times one-half the line frequency) and we were back to the value I had proposed to the FCC on May 5, 1950.

The chairman of the FCC, Wayne Coy, having dropped all semblance of judicial neutrality and annoyed by the criticism directed at him by RCA and many others, hit the lecture circuit to defend the FCC ruling on color television. He identified himself completely with the CBS cause and made bitter speeches against the press. Dr. Baker had invited the FCC to send staff engineers to attend the various NTSC panel meetings but Coy permitted attendance at only a limited number of demonstrations. Finally on February 21, 1952, Coy left the FCC and the new chairman, Rosel Hyde, immediately allowed staff engineers to take part in the NTSC activities.

Coy joined Time, Inc., which bought KOB-TV and its radio station in Albuquerque, New Mexico. Coy acquired control of fifty percent of this package and became the general manager. This gave me what I thought to be a splendid Machiavellian idea. We had all the necessary studio equipment which could generate a field-sequential color television signal, that is, a camera and the necessary synchronizing and switching apparatus as well as a couple of receivers equipped with rotating color disks. This apparatus had been constructed for all the interference tests conducted by Gordon Fredendall in 1949 and 1950. Since CBS had already ceased broadcasting of field-sequential color, I thought it would be appropriate to offer the field-sequential equipment to Coy so that there could be at least one station operating on the official color television standards which he had promoted. I went to Byron Jolliffe with my plan but he vetoed it on the basis that Coy might still have some influence in Washington and it would be best not to antagonize him further. I often wished that I had gone directly to David Sarnoff with this proposal for I

was rather sure it would appeal to him. Years later, when I mentioned this matter to DS, he said such a gesture would have made up for all the trouble Coy had caused.

While the various panels of the NTSC carried out testing of the field-test specifications of November 26, 1951, my colleagues were becoming less enchanted with Color Phase Alternation as receivers with brighter pictures became available. At high brightness, blue edges flashed in an annoying fashion and crosstalk bars flashed at one-half the field frequency. Similar observations were made by Hazeltine engineers and we began to compare notes and speculate concerning possible cures.

Bedford's studies of vision, made many years before, had prompted further investigations in depth. It was evident that three primary colors—red, green and blue—were required in the larger areas of a picture and that the fine detail could be supplied by monochrome signals or mixed highs. But it was later appreciated that in between these two conditions were small patches which could be color-matched by mixing a barely-orange red with a greenish blue or cyan. Investigations by Al Schroeder and Ray Kell led to a method of producing good color without CPA but with reduced distortion. In their solution, the signal would consist of a brightness signal proportioned to yield constant luminance and a subcarrier signal carrying two pieces of color information. One piece was to be a signal with moderate detail which distinguished orange-red from blue-green and the other piece supplying only coarse detail and distinguishing green from purple. This signal structure called OCW (orange-cyan wideband) was demonstrated to a number of panels of the NTSC in the summer of 1952 and further observations were soon made in other laboratories.

In November, another six days of broadcast of the new signal proved by viewer response that we did indeed have a compatible signal. Panel 13 was at the same time considering all the factors which might lead to pitfalls and produced a set of revisions of the signal for field testing to be considered by the other panels. When all the bases had been

covered, W. R. G. Baker caused to be published on February 2, 1953, *Revised NTSC Color Field Test Specifications.* By this time, Peter Goldmark and a few of his associates had joined the NTSC panel meetings and had made several constructive suggestions.

The spring of 1953 was a happy time for the results were most gratifying. All the details were wrapped up for a final proposal to the FCC. In the meantime, Gordon Fredendall and his crew had been hard at work. When the NTSC was field testing the first signal which used CPA, Fredendall patiently went through the task of getting data regarding cochannel interference and all the other types of interference which were of interest. As soon as we switched to the OCW system, he had his work to do all over again.

Early in 1951, we established a laboratory in Astoria, Long Island, about three miles from the Empire State Building for the purpose of testing receivers and these facilities were made available to all NTSC panels and members for observations and testing of any color receivers brought to this location. John Million had closed our Silver Spring laboratory and had come to take charge of the Astoria facility.

Because of the restrictions on our experimental broadcasting license, the laboratory was in use late at night. The NBC engineers at the Radio City studio were often in a quandary trying to meet the signal requirements of John Million at the same time that conflicting demands came from the engineers at our laboratory in Princeton.

We had planned some very critical tests to be made at RCA Laboratories one night in April, 1953. That same night, I was staying over in New York for an early morning meeting so I promised Ray Kell that I would drop by the NBC color studio around midnight to ensure the proper signal sequence for the Princeton tests. When WNBT ended its regular program at midnight, Ray Kell requested a test pattern, then color bars and several other devices for testing the received signal. After about thirty minutes of this, John Million telephoned from Astoria and demanded

a live color-camera picture. I refused his request and the tests continued.

John was persistent and I remained adamant. Finally at two in the morning, Ray Kell and his companions of the night were satisfied and ready to go home so I told the NBC engineers to take care of Million. He asked for a color television camera scene in the studio and also asked that Marie stand in front of the camera. Marie was a patient girl who often did just that.

Next, John ordered, "When I was in the studio this afternoon, I saw a bowl of fruit. Have Marie hold some fruit."

Marie was handed a pair of luscious yellow bananas. As she was walking toward the lights, I noticed a large bucket of blue paint left by some preparer of scenes. I quickly arranged the bananas on a pair of small sticks and while Marie daintily held the bananas I painted the two bananas a beautiful brilliant blue and sent the girl on her way. She posed in front of the camera while we waited for a response from John Million. In a few minutes the phone rang and I answered.

John said, "Don't you fellows ever look at your monitor? That picture is crazy."

I replied, "John, I assure you everything on the monitor is exactly as it is in the studio."

"I'll call you back," shouted John. "I will see what I can do with this receiver."

Time passed, five minutes, ten minutes, finally a half hour before the phone rang.

Finally, in disgust, John reported, "I've twisted the knobs so the bananas look all right but it surely wrecked the rest of the picture."

In May, 1953, the various panels had approved the results of the field tests and Panel 13 decided to recommend these signal specifications to the main body of the NTSC. When the motion to do so had been made, Peter Goldmark gallantly requested the privilege of seconding this motion. Twenty-nine organizations, including the Columbia Broadcasting System, were represented on the

main body of the NTSC and on July 21 all approved the technical signal specifications and on July 23 a petition on behalf of the NTSC was filed with the Federal Communications Commission proposing that the FCC adopt as standards for color television broadcasting the signal specifications which had been thoroughly field tested. This was a record-breaking response to Chairman Hyde's letter of July 9 requesting information on results of the NTSC field tests.

Individual petitions were also filed by Philco, Sylvania, General Electric and Motorola as well as a letter from the Hazeltine Corporation, all urging the adoption of the signal specifications which had been proposed by the NTSC. RCA jumped the gun by filing a 697-page document on June 25, much to the annoyance of many people from other companies who had worked so diligently and honestly with us. I did not approve of this affront to my professional friends who had trusted me.

The RCA petition referred to the "RCA Color Television System" which operated on "the color standards proposed by the NTSC." Our petition phrasing apparently aroused the Philco organization to submit a petition which was aimed more at denigrating the RCA contributions than it was to be constructive. It was so spiteful that David Sarnoff demanded that the Philco claims be discussed with him. In a letter of August 3 to DS, Engstrom, Jolliffe and I analyzed the Philco petition point by point, with sufficient documentation which showed that Philco had submitted a document replete with sly fabrications.

On September 18, the FCC asked for a demonstration of the proposed system and October 15 was selected for this event. NBC broadcast color signals on Channel 4 including transmissions of signals sent to Washington and back by microwaves and by coaxial cable. CBS participated with color transmissions on Channel 2 while Allen B. DuMont Laboratories provided signals by means of a UHF transmitter. Color test patterns, slides and live camera shots were available. At the Waldorf Astoria Hotel, thirteen color television receivers were provided by

thirteen organizations. Of these thirteen receivers, eleven used RCA shadow-mask color kinescopes while the remaining two had shadow-mask color kinescopes manufactured by others.

The commissioners seemed very pleased with the results. It was a different commission from the one I had faced so many times during the hearings. Coy, Jones and Walker had been replaced by Robert Bartley, John Doerfer and Robert E. Lee. Sterling, Webster and Hennock remained with Hyde as chairman.

Deep silence followed the demonstration except, in November, for a request for clarification on a minor point. Then on December 17, 1953, on the fiftieth anniversary of the Wright brothers' success, we also leaped into the air when we heard that the FCC had adopted the NTSC specifications as the law of the land with commercial broadcasting authorized to begin on January 22, 1954. Webster, Sterling and Lee had not only concurred but wrote separate statements in support of the decision. Commissioner Hennock was present at the December 17 meeting but for some unstated reason did not vote.

The work of the National Television System Committee was an outstanding example of cooperation on the part of a large number of engineers joined in an effort to bring about the best solution of a major technical problem of common concern. While the various panels weighed a multitude of factors, the major contributions were those of RCA and Hazeltine. For instance, the burst to synchronize the colors was a Bedford invention which prevailed in a lengthy patent interference. The use of a subcarrier where hue was determined by phase variation and saturation was measured in amplitude was described in RCA Exhibits 207 and 209. The NTSC choice of 455 times one-half of the horizontal line frequency was the same value which I had proposed at the FCC hearing and which was confirmed by our field testing in 1952. The orange-cyan wideband proposal came from RCA Laboratories and an appreciation of the principal of mixed highs made possible the success of the compatible system. Without question,

the constant-luminance principle came from Hazeltine Laboratories as well as much advice in regard to the composition of the color subcarrier. While not a part of the signal specifications or the standards, the Hazeltine concept of bypassed brightness apparatus contributed heavily to practical success in both studio equipment and receivers. Without the RCA shadow-mask color kinescope, the NTSC signal specifications would have been meaningless.

Without the contributions of RCA, which Philco tried hard to deny us, there would have been no NTSC solution. On the other hand, RCA unquestionably could not have received FCC approval on a system proposed by only one company for the FCC's collective fingers had been burned as a result of the FCC approval of the CBS incompatible color system.

NBC immediately began to broadcast some of its commercial programs in color on the appointed day. David Sarnoff was aglow with triumph and I believe he expected customers to rush to the television vendors the next day. Many of us who had participated in the development of the system and apparatus and had helped to formulate the standards believed the public would clamor for color television receivers immediately. Yet in 1959, six years after standards were adopted for color television broadcasting in the United States, only a few hundred thousand color television receivers were in use in the entire country.

We kept a stiff upper lip as we pretended that color was coming along wonderfully and as corporate money was expended at a great rate. The reasons for the small number of sets in use were many and complex. Some companies which had endorsed the standards in 1953 still failed to offer color sets for sale, some motivated perhaps by black-and-white sets in inventory, some perhaps in a sincere belief that color was not yet ready. Except for programs of the National Broadcasting Company, there was not much color broadcasting. But at least standards had been agreed upon completely so that if at any moment the fickle public decided that color television was the thing