TECHNICAL PROGRAM - II
Tuesday Morning, June 28, 1966

CHAIRMAN JAMES R. PALMER: Gentlemen, I'm Jim Palmer, C-Cor Electronics, welcoming you to the 8:30 A.M. Technical Session.

Our speaker is Blair Weston from Scientific-Atlanta, Inc. Blair studied electrical engineering at Auburn University not too many years ago, worked for awhile at Redstone Arsenal and Norton & Chimes Equipment Co. He has been with Scientific-Atlanta from 1961 to the present. Blair will talk on Analysis of CATV Antenna Array Characteristics Utilizing Radiation Pattern Measurements. Blair Weston.

MR. J. B. WESTON, JR. (SCIENTIFIC-ATLANTA, INC.): Thank you, Jim. First, I would like to express our appreciation for the opportunity of presenting this paper at the Convention this year. Before I get into the text, I would like to briefly explain the motivations which prompted the presentation of this paper.

Since the earliest days of CATV there has been little information available concerning the performance of tower-mounted antennas and antenna arrays. Most technicians have of necessity relied on manufacturers' literature concerning the mounting techniques and arraying techniques for antennas. At best this information has been incomplete. Secondly, since Scientific-Atlanta is a prime manufacturer of antenna pattern range test equipment, I had available a complete facility to analyze the performance of antennas and antenna arrays.

Radiation patterns, while not used extensively in the CATV field, provide a wealth of information. For example, the six most important specifications which determine the performance of an antenna or antenna array are gain, beamwidth, sidelobe levels, front-to-back ratio, null positions and VSWR. All of these features, with the exception of VSWR, can be readily determined or approximated from antenna radiation patterns. However, radiation patterns can be deceiving, if not interpreted properly. Consider this first slide. Of these 3 patterns, which would you prefer? Quite frankly, all 3 patterns are representative of the same antenna. The pattern in the upper left hand corner is plotted with respect to the power the antenna receives, and in the upper right hand corner with respect to voltage or field that the antenna receives. The lower pattern is a logarithmic or db plot of the same antenna. I believe you can see right off hand that the db plot at the bottom of the slide gives you a much better analysis of the lobe level, null positions, and generally speaking, a lot clearer presentation of the antenna's performance.

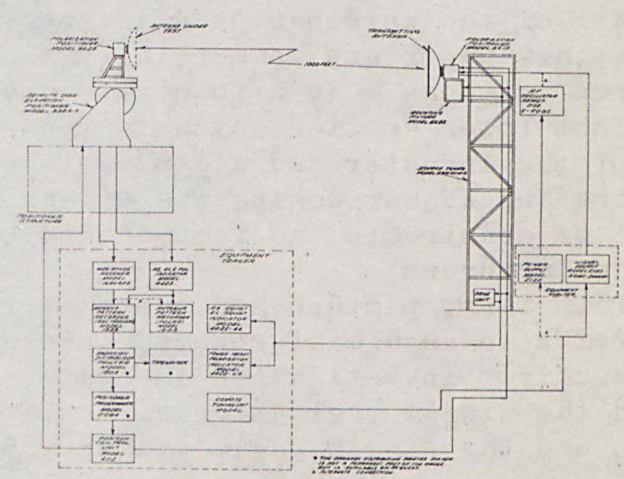

Fig. 1. Block Diagram of Scientific-Atlanta Antenna Pattern Range.

The next slide is a block diagram of the antenna range on which all the measurements in this paper were performed. Quite briefly, we have a transmitting antenna on the right hand side of the slide which is remoted from the receiving anteena or the antenna that you're testing. This receiving antenna is mounted on a three-axis positioner which allows you to rotate the antenna in azimuth, elevation and polarization. Synchronously coupled to this position is an antenna pattern recorder; the RF output from the antenna is fed through a receiver to the antenna pattern recorder. As we rotate the test antenna, the pattern recorder generates a radiation pattern of the antenna's characteristics.

The next slide is a picture of the console. In the left hand side, middle left hand side, you can see the receiver. The center section shows the recorder, it's kind of hid by the front panel there, but this is the polar recorder. Lower right hand section is the control equipment for positioning the antenna. The clock-like dials across the top of the console are synchro indicators which allow you to determine the antenna's position at a glance. All the radiation patterns in this report were recorded on Scientific-Atlanta's pattern range. The over-all accuracy of the levels is plus and minus a half a db and the angular read-out accuracy is better than plus and minus a degree.

All of the antennas used in preparing this paper are commercially manufactured antennas. We also constructed a 12 foot tower section which is typical of the industry and all mounting hardware and RF harnessing was either bought or constructed as recommended by the manufacturers.

This first picture here is what I will refer to as a mast-mounted antenna, and our first investigation is centered around the single-yagi antenna. A lot of you use the single yagi, either a 5

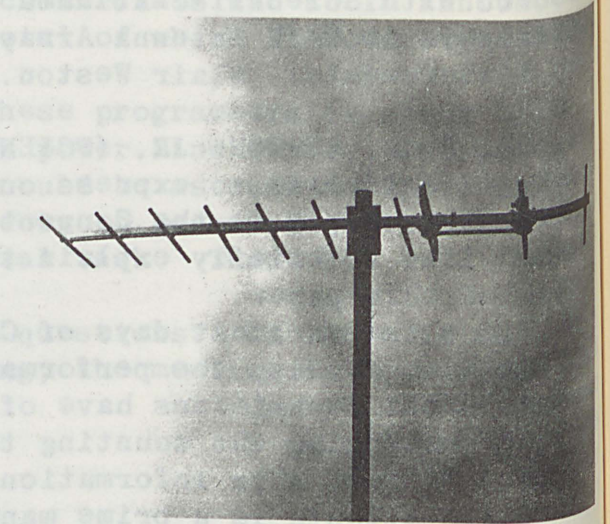

Fig. 2. Mast-Mounted Yagi

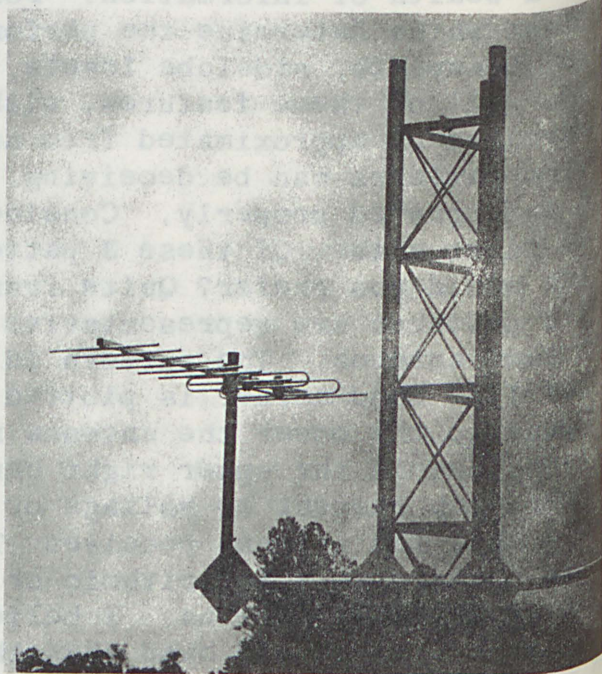

Fig. 3. Tower-Mounted Yagi

or a 10 element yagi for reception of local channels. And we were interested in finding out exactly what effects a tower would have on the performance of this antenna. This shows the mounting arrangement which we use for measurements taking the data on these antennas. Here again, the same antenna just side mounted on a tower. Incidentally, the spacing was approximately six-tenths of a wave length which is a little bit greater than that recommended by the manufacturer.

Our next slide shows the relative performance between these two configurations. The top three patterns are representative of the radiation patterns of a single yagi antenna mounted on a pole or a mast. The bottom three patterns are representative of the same antenna mounted on the side of a tower. You notice three patterns in each group. All the measurements contained in this report are in the frequency range of channel 13; the left most pattern at at 210 megacycles, the center pattern at 213, your right hand pattern at 216 megacycles. General characteristics of the mast-mounted yagi indicate half-power beamwidths on the order of 50 degrees, front-to-back ratio of approximately 20 db. The tower-mounted yagi shows essentially the same beamwidths, 50 degrees. The front-to-back ratio is considerably larger, the lobe has split and there is a fair amount of distortion on the left hand side of the pattern which is the side that the tower was on.

Continuing the investigation, we decided to analyze some of the performance specifications of vertical stacks. One of the more common vertical stacks is the so-called J stack. Here you see the configuration that we use for analyzing the performance of the J stack. Again, mast-mounted. We investigated two particular aspects of this J stack.

1) We connected the antennas with coaxial tees, providing a common output.

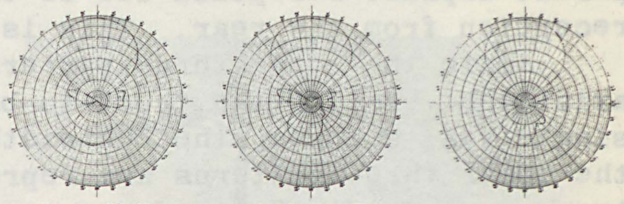

Fig. 4a. 210 MHz Fig. 4b. 213 MHz Fig. 4c. 216 MHz

Patterns of a Mast-Mounted Yagi

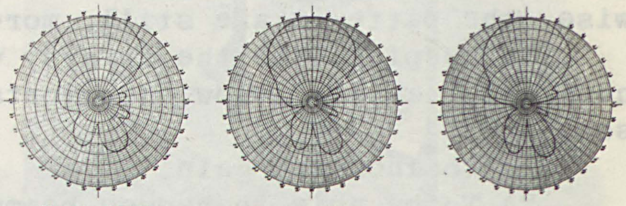

Fig. 4d. 210 MHz Fig. 4e. 213 MHz Fig. 4f. 216 MHz

Patterns of a Tower-Mounted Yagi

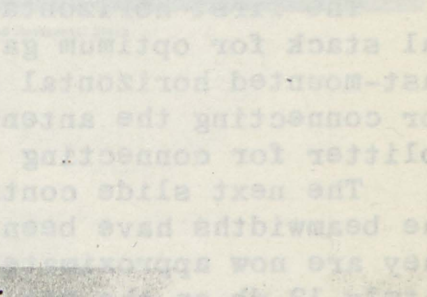

Fig. 5. Mast-Mounted "J-Stack" for Co-Channel Elimination

2) We connected the antennas with a two-way power splitter, to provide a single output.

As you know, the operation of the J stack is based on a physical separation of antennas of a quarter wave length and the use of a delay line to permit inphase reception off of the front of the antennas and out of phase reception from the rear. This is commonly used for co-channel rejection.

Again the upper three patterns are shown with respect to using a coaxial tee. Notice the front-to-back ratio has improved some 5 db over the single yagi antenna, the beamwidths are essentially the same at 50 degrees, the lower three patterns are representative of the same array utilizing a two-way power divider and, as you can see, the front-to-back ratio has improved substantially beyond that which we attain with coaxial tee. Otherwise, the patterns are still, more or less, identical.

In keeping with the arrays, we decided to analyze the performance of horizontal arrays. Now, horizontal stacking is used for a number of reasons:

1) To increase gain.

2) To be able to reduce beamwidths.

3) Use nulls to help eliminate co-channel.

The first horizontal array which we investigate here is the horizontal stack for optimum gain. We tried two particular configurations of this mast-mounted horizontal stack. Number one again utilizing a coaxial tee for connecting the antennas and, secondly, utilizing a two-way power splitter for connecting the antennas.

The next slide contains the performance of these two configurations. The beamwidths have been reduced considerably from the single antenna; they are now approximately 25 degrees. The side lobe level is approximately 13 db on the top three patterns; they average out around 13 db. Certain amount of asymmetry in the patterns which can be attributed to the tee. The lower three patterns are representative of the same array, utilizing the two-way power divider. You will notice a lot better symmetry in the patterns. The sidelobes are now almost equal at 13 db, beamwidths still approximately 25 db - 25 degrees.

Additionally we wanted to investigate the effects that a tower would have on this optimum stack and this optimum stack provides mounting the antennas approximately a wave length and a quarter apart.

So, the next slide shows the configuration in which we investigated the following:

Two antennas are mounted very similar to what you see in the industry with, again, one and a quarter wave length spacing.

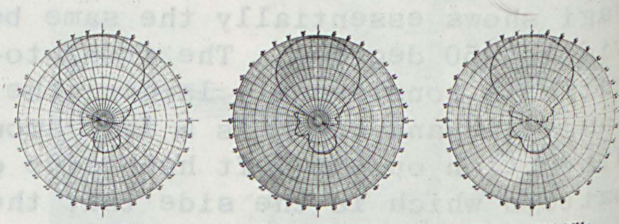

Fig. 6a. 210 MHz　Fig. 6b. 213 MHz　Fig. 6c. 216 MHz

Patterns of a "J-Stack" using Coaxial "Tee"

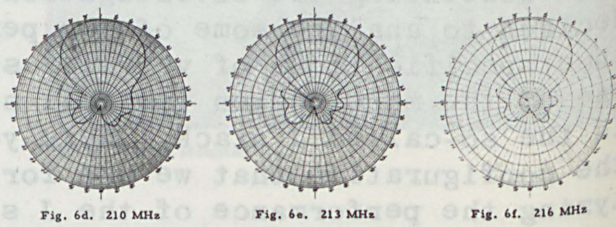

Fig. 6d. 210 MHz　Fig. 6e. 213 MHz　Fig. 6f. 216 MHz

Patterns of a "J-Stack" using Two-Way Power Divider

And the next slide contains the patterns from the previous data slide, the same three patterns at the top which show the mast-mounted stack, utilizing a two-way power divider. The bottom three patterns show the tower-mounted horizontal stack, with a two-way power divider. I think you can see quite readily that the sidelobe levels have increased some 3 to 4 db and the front-to-back ratio has increased somewhat with the definite enlargement of the rear lobes on the antenna patterns.

Horizontal spacing to force nulls is quite often used, and we additionally investigated some of the effects of horizontal spacing. The next slide shows our first investigation, that of forcing nulls at 40 degrees. As all of you know, I presume, it is quite readily calculated exactly what spacing is needed between antennas to force nulls. We wanted to force a null at 40 degrees; calculations indicate that 7/10ths wavelength spacing between antennas should be used. You can see the nulls are quite accurately predictable.

Here again we have with this particular spacing on a horizontal stack, beamwidths of approximately 36 degrees as opposed to 25 degrees for the optimum stack. The mast-mounted version of the top three patterns exhibits a front-to-back ratio very close to that of the performance obtained with the single antenna. Sidelobes are down considerably. The extra width of the pattern contributes overall to a gain reduction in the performance of this horizontal stack. The second three patterns are representative of this same array mounted on a tower. I believe it's quite evident the distortion introduced by the tower - essentially the nulls were lost in the confusion of the patterns. Front-to-back ratio is shot to -- just plain shot down.

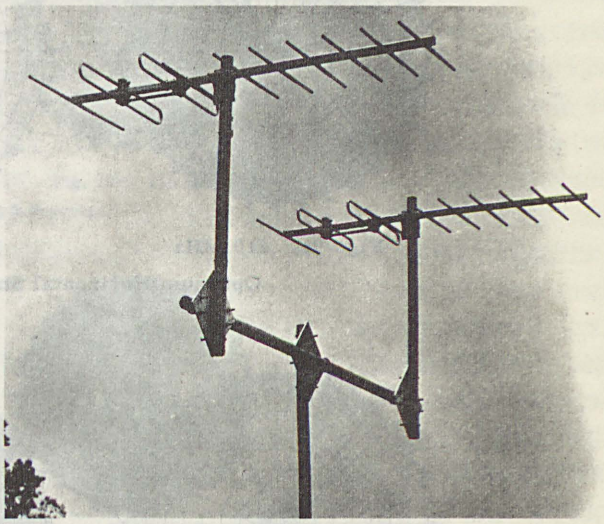

Fig. 7. Mast-Mounted Horizontal Stack

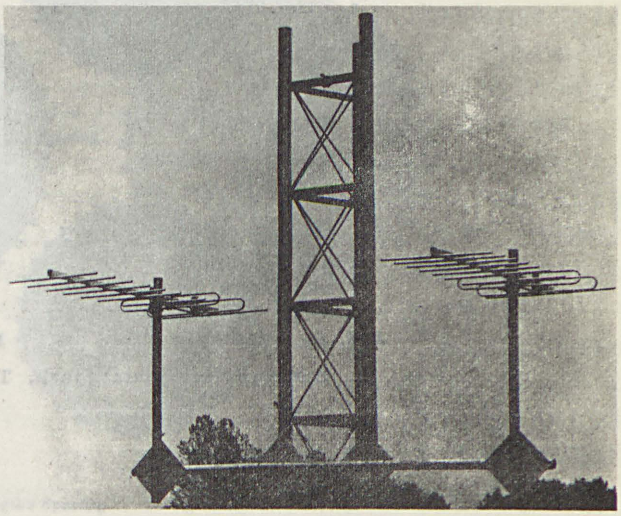

Fig. 8. Tower-Mounted Horizontal Stack

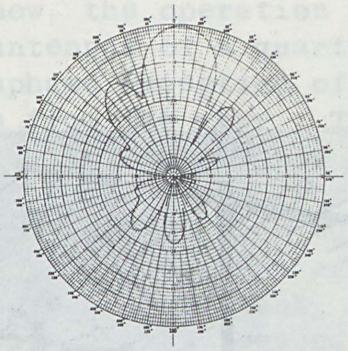

Fig. 9a. 210 MHz

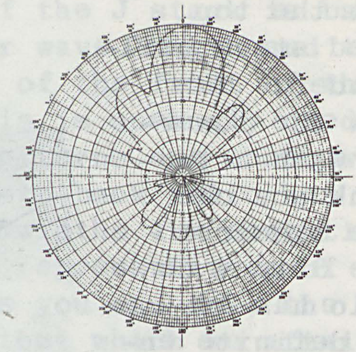

Fig. 9b. 213 MHz

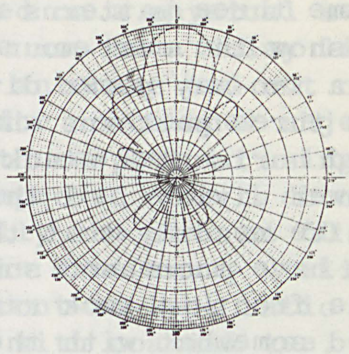

Fig. 9c. 216 MHz

Optimum Horizontal Stack, Mast-Mounted, using Coaxial "Tee"

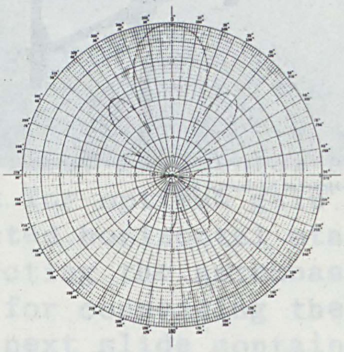

Fig. 9d. 210 MHz

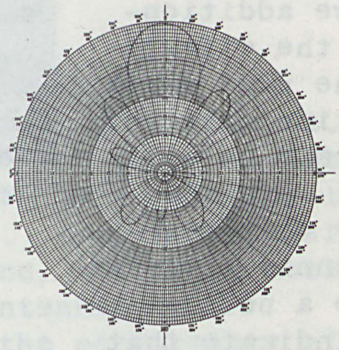

Fig. 9e. 213 MHz

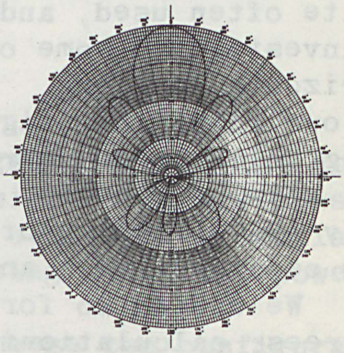

Fig. 9f. 216 MHz

Optimum Horizontal Stack, Mast-Mounted, using Two-Way Power Divider

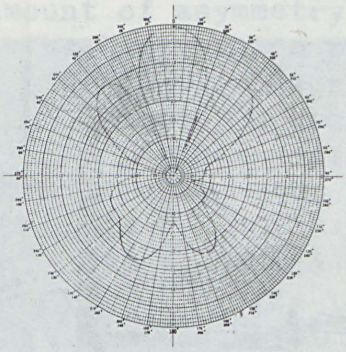

Fig. 9g. 210 MHz

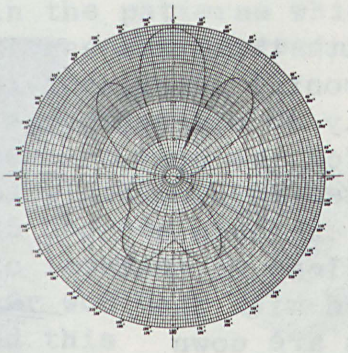

Fig. 9h. 213 MHz

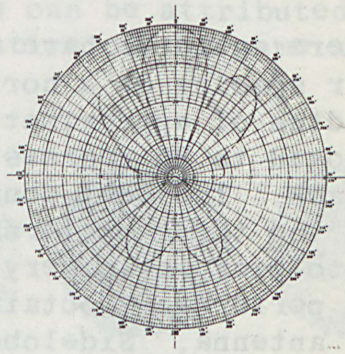

Fig. 9i. 216 MHz

Optimum Horizontal Stack, Tower-Mounted, using Two-Way Power Divider

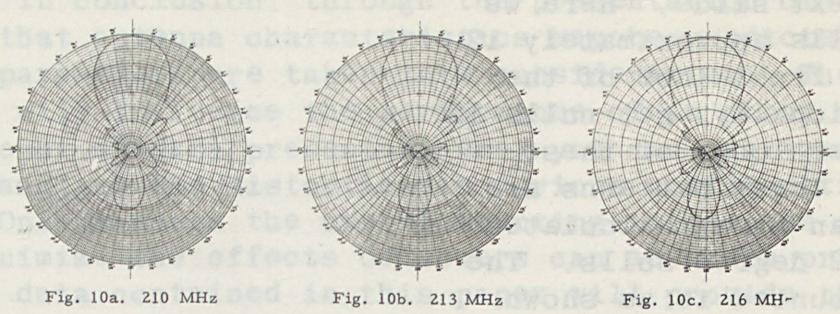

Fig. 10a. 210 MHz Fig. 10b. 213 MHz Fig. 10c. 216 MH-

Horizontal Stack, Mast-Mounted, 0.7 Wavelength Spacing

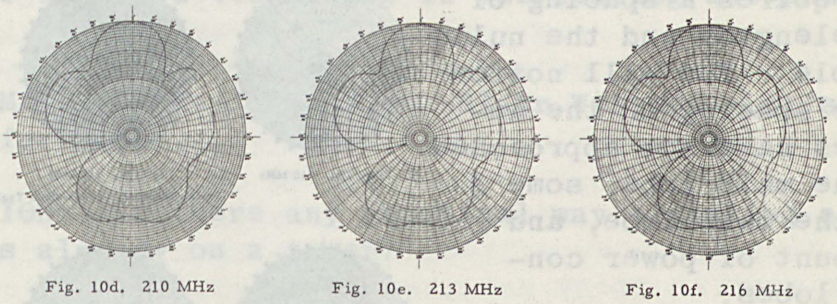

Fig. 10d. 210 MHz Fig. 10e. 213 MHz Fig. 10f. 216 MHz

Horizontal Stack, Tower-Mounted, 0.7 Wavelength Spacing

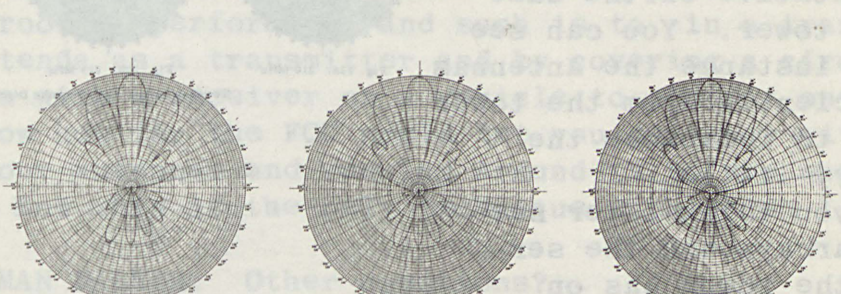

Fig. 11a. 210 MHz Fig. 11b. 213 MHz Fig. 11c. 216 MHz

Horizontal Stack, Mast-Mounted, 2.5 Wavelengths Spacing

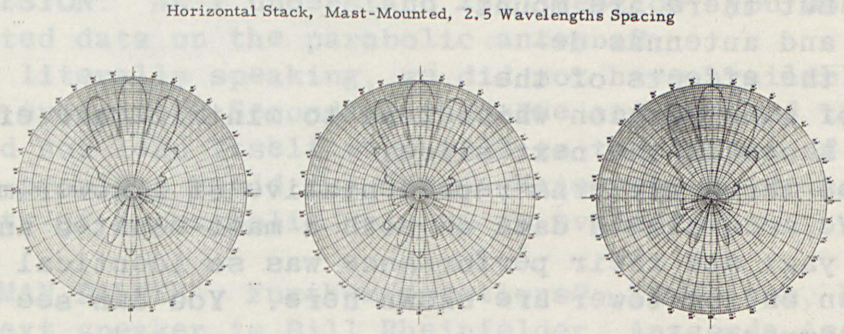

Fig. 11d. 210 MHz Fig. 11e. 213 MHz Fig. 11f. 216 MHz

Horizontal Stack, Tower-Mounted, 2.5 Wavelengths Spacing

The second investigation on the nulling utilizing horizontal stack is contained in the next slide. Here we wanted to place nulls approximately 12 degrees off of the front lobe of the pattern and, additionally, get nulls 12 degrees off the rear lobes of these patterns. The top three patterns are representative of an array calculated to provide these 12 degree nulls. The performance mast-mounted is as shown in the top three patterns. Again, calculating the nulls requires a spacing of two and a half wavelengths and the nulls are quite predictable. You will notice that with this wide spacing on the antennas the sidelobes have now approached the amplitude of the main lobe, some 2 or 3 db down from the main lobe, and there is a fair amount of power contained in the side lobes.

The second set of patterns on the bottom are representative of the same array mounted on a tower. You can see in this particular instance the antennas were remoted sufficiently from the tower to allow the tower to influence the characteristics very little.

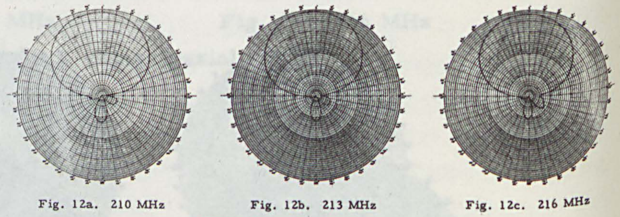

Fig. 12a. 210 MHz   Fig. 12b. 213 MHz   Fig. 12c. 216 MHz

Tower-Mounted, Screen-Back Yagi

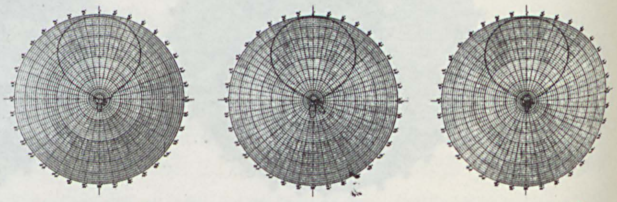

Fig. 13a. 210 MHz   Fig. 13b. 213 MHz   Fig. 13c. 216 MHz

Tower-Mounted, Log-Periodic Dipole

Now, perhaps you think after seeing some of these arrays and the serious effects that the tower has on their performance, that there's no way to get around it. But there are mounting configurations and antennas designed to minimize the effects of the tower. Two types of construction which tend to minimize the effects of support towers are shown in the next slide.

We have the top three patterns representative of a tower-mounted screenback yagi. We accumulated data on both a mast-mounted and tower-mounted screenback yagi and their performance was so identical that only those patterns taken on the tower are shown here. You can see the performance is quite respectable.

A second method of construction which tends to minimize the effects of towers is that of log-periodic dipoles. The second set of patterns on the bottom of the slide are representative of the performance obtainable with log-periodic dipoles mounted on a tower. Again the performance between the log-periodic dipoles on the tower and mast-mounted were so similar that only the tower-mounted patterns are shown. Incidentally, these antennas were cantilever-mounted from the tower. I trust all of you are familiar with this mounting arrangement. As you can see the performance of these antennas is very respectable.

Well, in conclusion, through the presentation of data I hope I have shown you that antenna characteristics may be predicted only when all influencing parameters are taken into consideration. The support tower in most cases will influence the performance of an array. Even with the limited amount of data presented here, you can realize the difficulty of trying to analyze the distortion in various configurations a tower might present. Only through the use of mounting techniques and antennas which tend to minimize the effects of towers can accurate prediction be made. I hope the data contained in this paper will provide the CATV technician with a better understanding of antenna array performance and will provide a basis for improved techniques in fabricating antenna arrays. I thank you.

CHAIRMAN PALMER: Thank you, Blair Weston. Let's proceed with questions for Blair.

QUESTION: Is there any practical way of taking antenna array patterns on antennas already on a tower?

MR. WESTON: It's somewhat difficult to rotate towers to obtain patterns, although I believe one of the common practices in the broadcast field is proof of performance and such is to, in a transmitting situation, use the antenna as a transmitter and by covering a circular path around the antenna with a receiver on a vehicle to plot it out point by point. I don't know how far the FCC would let you get away with the applying power to your antennas and running around it to see what the characteristics are. But this is the only technique with which I would be familiar.

CHAIRMAN PALMER: Other questions?

MR. WESTON: As I understand the question, you wonder why we have not presented data on the parabolic antenna?

Well, literally speaking, we did not have available the parabolic antenna to evaluate. Secondly, the size and such of the parabolic antenna would not lend itself very well to the taking of measurements due to various problems you'd run into. Main reason, we have not had the availability of a parabolic antenna to evaluate.

CHAIRMAN PALMER: Further questions? Thank you, Blair.

Our next speaker is Bill Rheinfelder, Anaconda Astrodata. Bill was staff consultant at Motorola, high frequency applications 1957 to 1961. During the end of this period he also acted as a consultant for AMECO and left Motorola at that, somewhat thereafter, to go to AMECO as Director of R&D. Then in 1965 he joined Astrodata as Director of Research and Development - CATV in Anaheim, California. Bill Rheinfelder has his masters of science and electrical engineering from the Institute of Technology at Munich, Germany. Bill will talk to us on Advanced CATV System Concepts.