"SIMULSAT" *
A SIMULTANEOUS MULTIPLE SATELLITE ANTENNA TVRO

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Abstract:-SIMULSAT is a Simultaneous Multiple Satellite Antenna Terminal. It was developed by ANTENNA TECHNOLOGY CORPORATION as a result of the demands placed on Cable T.V. operators and television stations to have TVRO systems to view more than one satellite simultaneously without creating an antenna farm. SIMULSAT behaves as a 5-meter antenna over a full 57 degree arc. It is a quasi-parabolic reflector antenna. Gain, radiation patterns, and comparison tests with 5-Meter antennas indicate that SIMULSAT performs very nearly like a typical 5-Meter antenna used as a TVRO. It has the capability of viewing all satellites from Sat Com 4 at 83 degrees to Sat Com 3 at 131 degrees with uniform performance from anywhere in the United States. It has been installed in more than a dozen systems including Teleprompter, Viacom, Heritage and G. E.

I. INTRODUCTION

The demands placed on Cable T.V. operators and television stations to view more than one satellite simultaneously have dictated the need for a multiple satellite antenna. Ideally, such an antenna should provide uniform performance over it's full arc. Indeed, such an antenna exists. It is ANTENNA TECHNOLOGY CORPORATION'S SIMULSAT antenna. SIMULSAT is a quasi-parabolic spherical reflector antenna capable of multiple satellite operation. It covers a 57 degree arc. Degraded performance occurs beyond those limits.

II. BACKGROUND

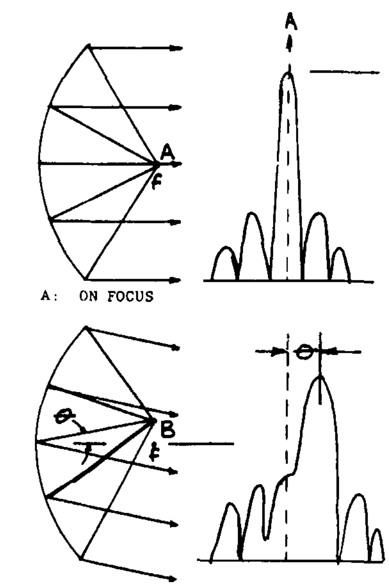
There are three general classes of antenna to provide wide angle multiple beam operation. These are the Torus, the Offset Spherical, and the spherical which is the class to which Simulsat belongs. In many respects the Torus and the SIMULSAT are very similar. However, a major difference is that the Torus is offset fed in the vertical plane while SIMULSAT is symettrically fed in both planes. Additionally, the Torus is a parabolic contour in the vertical plane and a circular contour in the orthogonal plane. SIMULSAT is quasi-parabolic in both planes. The Offset Spherical Antenna is in reality an approximation to an extremely long focal length parabolic reflector antenna.

III. PARABOLIC SCANNING

In Figure I we consider parabolic beam scanning or parabolic multiple beam operation. A feed placed at the focal point (A.) will produce a beam from the reflector back through the focal point as shown in the Figure. The displacement of the feed in a transverse plane to the reflecting system to (B.) will produce a linear phase shift across the aperture, thus changing the direction of the beam by the angle-θ-. If the reflector were a flat mirror, the beam shift would be linear, and in the opposite direction to the transverse motion of the feed. However, because of the narrow field reflecting system, a coma is introduced which tends to shift the beam in the opposite direction to that of the linear phase shift as well as the introduction of a loss in gain. Thus, a one to one correspondence between angular displacement of the feed and the secondary radiation pattern is not obtained. Further, the decrease in gain increases more or less exponentially as one moves away from the focal point of the narrow field reflecting system. Hence, parabolic multiple beam antennas produce maximum gain only on axis. As one moves off axis, directivity is reduced, the beamwidth broadens , and coma lobes increase. The coma lobe increases on the side of the beam toward the focal point. With an $\frac{F}{D}$ of one; that is, the focal length equal to the diameter, approximately nine or ten beamwidths can be scanned with 1 dB loss in gain.

* SIMULSAT is the Reg. T/M of A.T.C.

However, the sidelobe degradation is significant. With an $\frac{F}{D}$ of .5 such as that found in conventional earth terminal antennas, one can displace about 4 or 5 beamwidths for 1 dB degradation.



A: ON FOCUS

B: TRANSVERSE SHIFT

FIGURE 1:
PARABOLIC BEAM SCANNING

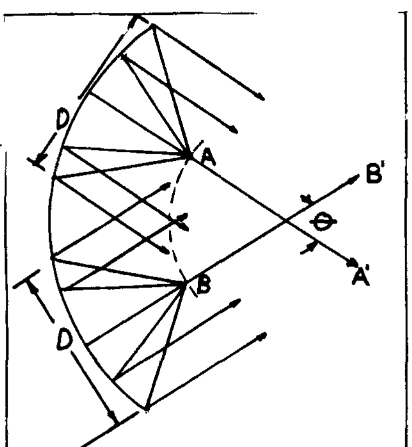


FIGURE 2: SPHERICAL BEAM SCANNING

IV. SPHERICAL SCANNING

Spherical beam scanning or multiple beam operation is shown in Figure (2). Here a feed illuminates only a portion of the reflector , the area represented by the aperture. The feeds are placed along an arc such that the aperture is scanned along the reflector to the various locations. A feed looking at reflector segment A, produces a beam in the A direction while a feed looking a reflector segment B produces a beam in the B direction. Here the feed illuminates the reflector consistently for all beam positions and thus performance is the same for all beam positions until one starts to actually look over the edge of the reflector. Scanning is only limited by the physical size of the reflector and that point at which the opposite edge of the reflector begins to block the reflected waves from the operational zone of the reflector.

V. SIMULSAT SCANNING

SIMULSAT utilizes the on-focus beam principle in the elevation plane and the Spherical Beam Scanning principle in the azimuth plane.

One can determine the angular arc coverage of SIMULSAT. As feeds are moved from Position A to Position B along the feed arc, the beam moves through the angle Theta. Thus, the angle Theta is the maximum angle that can be covered without degradation in performance. For a given reflector size, the longer the focal length--the smaller will be the angle Theta. In it's present configuration, the angular arc coverage of SIMULSAT is in excess of 57 degrees.

The 57 degree arc coverage does not mean to imply that SIMULSAT will view all satellites over a 57 degree orbital arc. Figure 3. shows the geometrical relations between the earth and satellites in orbital arc. From the center of the earth as shown in the Figure the angle Alpha depicts the angular coverage required to view an orbital arc. In the Equitorial Plane from the center of the earth it is precisely the longitudinal difference between the satellites. However, as one moves along the polar axis from the equitorial plane, the distance to the satellites increases and hence angular the arc coverage requirement decreases.

As one moves from the polar axis to the surface of the earth as shown in the Figure at point A, the distance to the satellites decreases and hence the angular coverage Beta increases. Thus, the angular arc coverage requirement of an antenna on the earth surface is a maximum at the equator and decreases as one goes North of the equator.

Additionally, the angular arc coverage requirement North of the equator is greatest when the center of the arc is due South and the angular arc decreases as the site location moves east or west.

For the United States, the maximum antenna arc requirements to see all satellites from Sat Com 3,at 131^{o} to Sat Com 4 at 83^{o} is 55 degrees. SIMULSAT currently has more than a 57 degree capture angle. Thus, SIMULSAT is capable of viewing all satellites in domestic arc from Sat Com 3 to Sat Com 4 from any point in the United States.

SIMULSAT CONSTRUCTION

Figure 4 is a photograph of a SIMULSAT installation in California. SIMULSAT consists of the reflector, the feed support structure, the universal mount, and the feed system. The reflector is a composite reinforced fiberglass structure. The reflecting surface is Hexcel Thorstrand aluminized woven fiberglass cloth. The structure is a combination of woven roving and fiberglass chop. The finish is ultraviolet resistant polyester gel coat. The reflector is made on precision tooling such that no field adjustments of the three segments of the reflector are necessary. Preassembly and inspection in the factory prove the surface to be within .150 inches peak deviation. The reflector weighs approximately 2,000 pounds.

The mount is available in two configurations--a high mount and a low. The choice of mount is dictated by the location. Figure 5 is a photograph of a SIMULSAT installation in Orlando, Florida. As can be seen in the photograph, the antenna is rolled approximately 30 degrees. This is so that the feed arc lines up with the equitorial arc at the center of the equitorial arc. Two different locations for a SIMULSAT antenna , one due north of the center of the equitorial arc and the other east only of the equitorial arc center are depicted in Figure 6. When looking due south, the equitorial arc appears to be horizontal with respect to the antenna, as one moves to the east the arc remains the same but the earth curves away from the antenna and thus the antenna must be rolled in the opposite direction to compensate for the curvature of the earth. As one moves further and further east and further and further North the corner of the antenna gets closer and closer to the ground thus necessitating the use of a higher mount.

The feeds are placed on a track in the feed housing that allows adjustment of each individual feed in azimuth, elevation and polarization with respect to the geostationary orbital arc. Precise alignment of the reflector at a location is not critical since the feed support structure has more than four degrees adjustment capability. Dual polarization is provided through a dual othogonal transformer developed by ANTENNA TECHNOLOGY CORPORATION.

This OMT is physically small and has the LNAs parallel to the beam axis. The system will accommodate all major manufacturer's LNAs and LNCs.

SIMULSAT has the performance characteristics of a typical 4.6 to 5-Meter antenna for each and every beam position across it's 57 degrees of arc.

RADIATION DATA

In order to substantiate the performance claims on SIMULSAT, ANTENNA TECHNOLOGY CORPORATION measured the radiation patterns on a typical production SIMULSAT antenna. The tests were conducted on Comtech Antenna Corporation's range in St. Cloud, Florida. In addition, these tests were witnessed by Comsearch to verify their authenticity. A typical close-in radiation pattern of the mainlobe and close-in side-lobe structure is shown in Figure 7. Also shown are the FCC guidelines for small aperture antennas and the 6 dB averaging limit. The radiation pattern for the far-out side-lobes on a different azimuthal scale is shown in Figure 8. It has the same guidelines and 6 dB limit shown. As seen in these radiation patterns, SIMULSAT does not exceed the averaging limit and meets the general requirements of the FCC guidelines.

We recommend frequency coordination on any antenna be done to the averaging limit. The justification for this is that should an antenna have a sidelobe that exceeds the guideline but is within the averaging limit and that sidelobe happens to be in a direction of a terrestrial interference source, then averaging it with adjacent sidelobes will not reduce the energy content of that sidelobe. An interference condition could exist if one coordinated to the FCC guideline rather than the averaging limit. By coordinating to the averaging limit you are taking the worst possible case and generally the system will behave much better than the coordinated prediction.

The radiation pattern tests were performed with 6 feeds in SIMULSAT--two feeds were located at the left edge of the antenna; two feeds were located in the center of the antenna; two feeds were located at the right edge of the antenna. This was so that adjacent satellite interference levels could be checked on the antenna range. The maximum angular arc between the two feeds within the housing was 57 degrees. Thus, SIMULSAT has the capability of operating over 57 degrees. The measured gain on all beam positions was 44 dB. Thus, SIMULSAT has the gain of a typical 5-meter antenna.

The radiation patterns are such that they can be coordinated for FCC licensing.

PERFORMANCE COMPARISON TESTS

Gain and sidelobes are not the only criteria for the performance of an antenna. One also has to consider the noise temperature. Noise temperature is the most difficult perameter of an antenna to measure, but quite a bit of work has been done on 5-meter antennas. Antenna Technology Corporation performed comparison tests between SIMULSAT and a 5-Meter prime focus antenna at the same location. Carrier to noise measurements were made on several transponders on several satellites in a short time frame on both antennas. The same electronic equipment was used for all tests. The only change was the substitution of SIMULSAT for the 5-meter antenna. In all cases the carrier to noise measurements indicated between 0.5 and 1 dB; better carrier to noise ratio for the 5-meter antenna than was achieved with the SIMULSAT. Noise floor measurements showed SIMULSAT to have .1 to .2 dB higher noise floor. Thus SIMULSAT has about 10 degrees higher noise temperature than a typical 5-meter antenna. If one considers that the 5-meter antenna under test had 44.5 dB gain as opposed to the 44 dB gain for SIMULSAT and the .1 to .2 dB difference in noise floor for SIMULSAT, then good correlation exists with the indicated .5 to 1 dB difference.

In addition to the test conducted by A.T.C. at it's facility, Viacom Cablevision conducted side by side tests on SIMULSAT and on a 5-meter Scientific Atlanta Cassigrain antenna. Both antennas are located on a mountain top located near Pittsburgh, California and within site of the Microwave tower installations on Mt. Diablo. Viacom conducted tests on Sat Com 1, Com Star D2 and Anik 3. Their measurements also indicated an average of 1 dB better performance in the 5-meter than SIMULSAT. Thus, we have correlation between two 5-meter measurements and SIMULSAT to show that SIMULSAT behaves very nearly like a 5-meter antenna.

Table I is a Performance Survey for SIMULSAT.

Frequency:
3.7-4.2 GHz
Gain (4GHz):
44 dBi
Beamwidth:
1.0 degrees
Minimum Satellite Separation:
3 degrees
Maximum Beam Separation:
57 degrees
Polarization Isolation:
25>dB
Adjacent Satellite Isolation:
25>dB
Feed Flange:
CPR 229-G
Size:
16' x 28'
Reflector:
Universal
Mount:
3 piece fiberglass
Wind:
125 Miles per hour-12 cubic yard foundation.

TWO DEGREE SPACING

Recently the FCC proposed a change in Satellite spacing from the current 4 degrees to a future 2 degrees spacing for 4/6 GHz satellites. At the present time we don't know whether or not this will become a reality. A decision won't be available from the FCC until June or July of 1982. The industry has been asked to comment on a technical and cost impact of such a proposal. If the FCC does decide to go to 2 degree spacing, it is my feeling that such a change would not and perhaps could not be implemented prior to 1988 or 1990. This would give manufacturers time to redesign their equipment. At that time operators with 5-meter antennas may have problems. Most typical cassigrainian antennas have a first sidelobe on the order of 12 to 15 dB below the mainlobe. This first sidelobeoccurs almost universally at two degrees from the mainlobe on either side of the mainlobe; hence, the first sidelobe is looking directly at the adjacent satellite when the mainlobe is looking at the desired satellite. The radiation pattern isolation is 12 to 15 dB. For an equal level of ca-rier on adjacent satellites on either side, the carrier to interference ratio would be about 9 dB. This would most likely result in interfering video in the desired signal or "sparklies" may be present, making an undesirable signal. Thus, the antenna will have to be reworked.

SIMULSAT behaves very much like a cassigrainian antenna at 2 degree spacing in it's present configuration. SIMULSAT would have the same relative isolation and carrier to interference problems as a typical cassigrainian 5-meter antenna.

A.T.C. is currently working on the development of a new feed for SIMULSAT which will be retrofitable to the present system. It will cost about the same as a spare feed presently costs and preliminary indications are that it will meet the new proposed antenna guidelines for 2^o spacing. This feed system should be available in mid-1983. In any event the change proposed by the FCC would most likely not be implemented prior to 1988 or perhaps 1990. Thus an operator investing in a system today has about 8 years of operating life over which to amortize that system and wait until new developments in the antenna field are available which would make the FCC specification a reality.

COST COMPARISON

In considering SIMULSAT for an operation one must compare the true cost and not the purchase price of SIMULSAT versus the purchase price of several 5-meter antennas. There is a hidden value arising from the fact that there is only one foundation to design, only one foundation location, and only one time that the crew has to go out and perform the installation. Additionally, an antenna farm is not created, less real estate is taken and the environmental impact of one antenna is not compounded by the environmental impact of several antennas in an antenna farm. Again, only one building permit has to be obtained, only one planning commission involvement and the myriad of other hindrances associated with the installation of a TVRO are performed only once with SIMULSAT. Up to 20 feeds can be placed in the feed housing. An operator can always have a spare feed on the shelf so that he can add a live feed at any time without disruption of service. This is an inexpensive method of obtaining additional services.

CONCLUSION

For an antenna for today, SIMULSAT is the most advanced antenna of it's kind. It's a new generation of antenna for today and will be with us for at least 8 years. When one considers that the FCC only opened the industry to small aperture antennas about four years ago, one indeed does come to the conclusion that the advancements made by SIMULSAT truly represent the next generation of antenna. It provides 5-meter performance over a full 57^o arc; it is fully FCC licensable, and it is available with more than a dozen currently in operation for single users and MSO's such as VIACOM, HERITAGE, TELEPROMPTER and G.E.

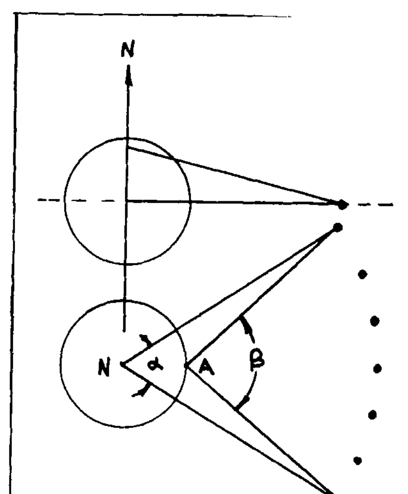
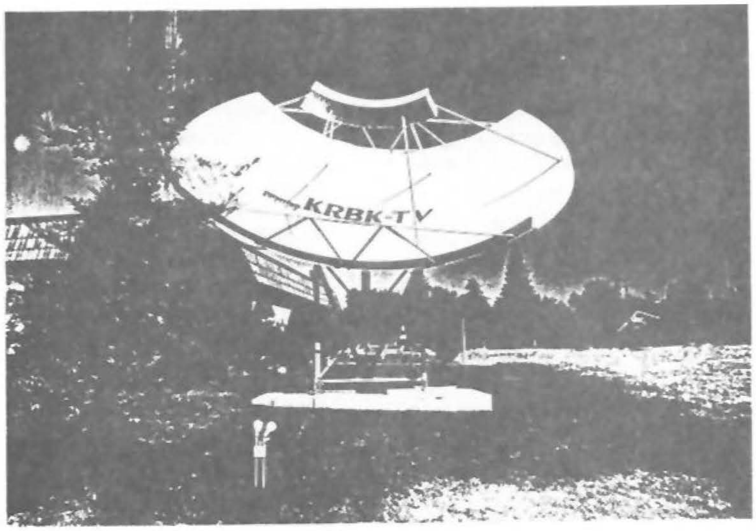


FIGURE 3: ORBITAL AND ANTENNA ARC.

FIGURE 4: WESTERN INSTALLATION
(ANTENNA IS NEARLY HORIZONTAL.)



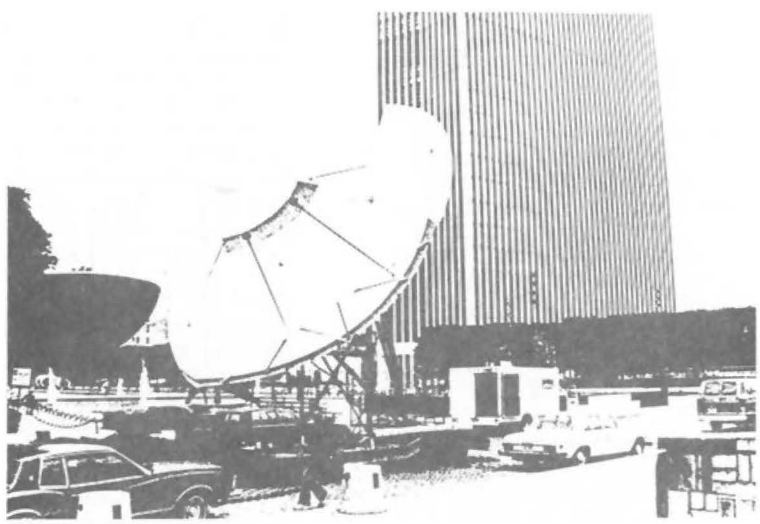


FIGURE 5: EASTERN INSTALLATION (ANTENNA IS ROLLED.)

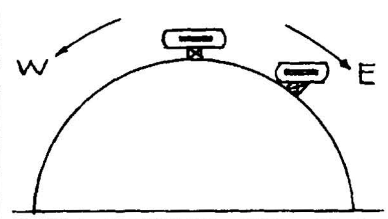
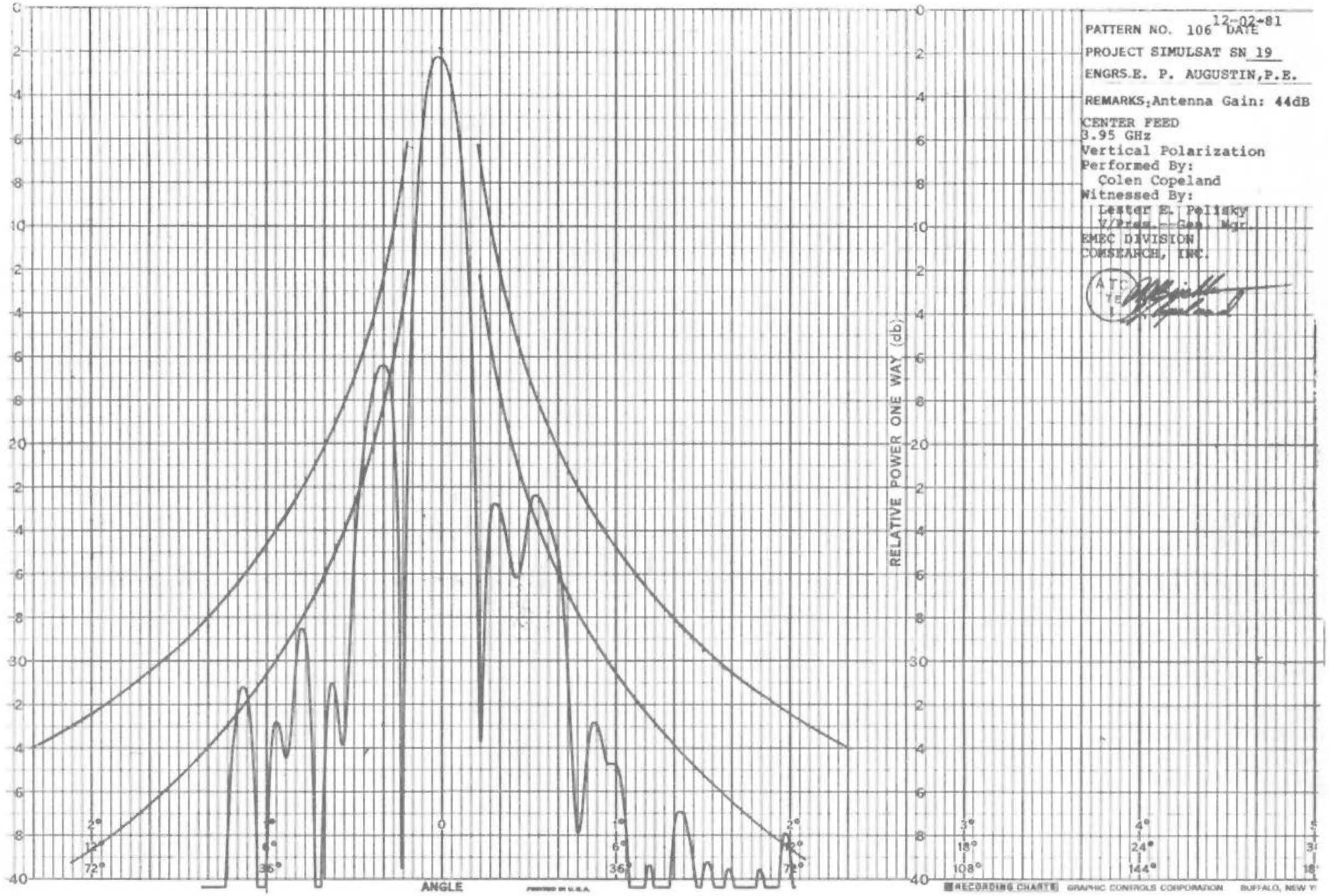


FIGURE 6: SIMULSAT ROLL ANGLE REQUIREMENT

FIGURE 7: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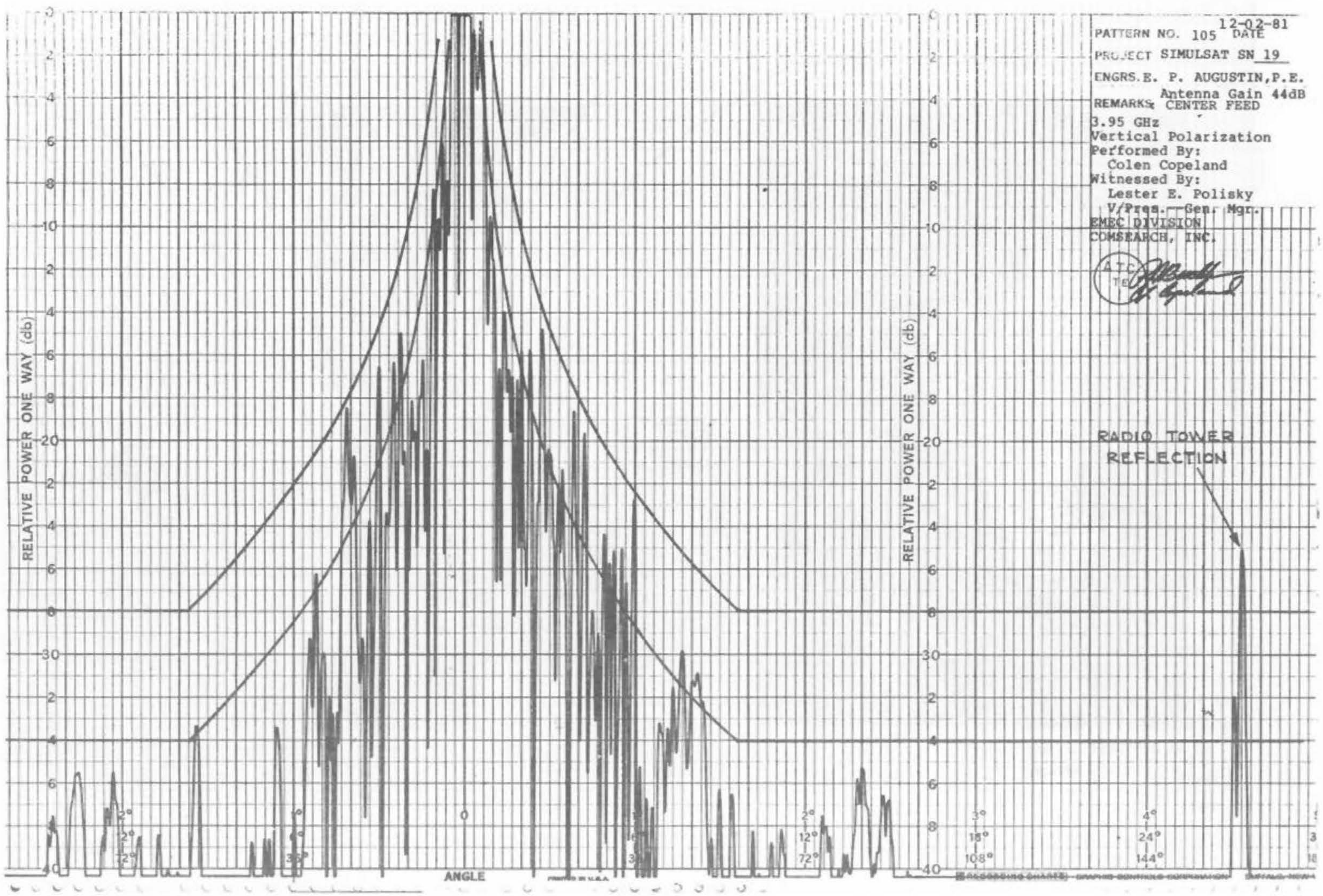
PROJECT SIMULSAT SN 19
ENGRS.E. P. AUGUSTIN,P.E.
REMARKS:Antenna Gain: 44dB
CENTER FEED
3.95 GHz
Vertical Polarization
Performed By:
Colen Copeland
Witnessed By:
Lester E. Polisky
V/Pres.--Gen. Mgr.
EMEC DIVISION
COMSEARCH, INC.
RELATIVE POWER ONE WAY (db)
ANGLE
RECORDING CHARTS GRAPHIC CONTROLS CORPORATION BUFFALO, NEW Y

FIGURE 8:


PATTERN NO. 105 DATE 12-02-81
PROJECT SIMULSAT SN 19
ENGRS. E. P. AUGUSTIN, P.E.
Antenna Gain 44dB
REMARKS: CENTER FEED
3.95 GHz
Vertical Polarization
Performed By:
Colen Copeland
Witnessed By:
Lester E. Polisky
V/Pres. - Gen. Mgr.
EMEC DIVISION
COMSEARCH, INC.
RELATIVE POWER ONE WAY (db)
RADIO TOWER REFLECTION
ANGLE