RADIO CORPORATION OF AMERICA
ENGINEERING PRODUCTS DEPARTMENT, Camden, N.J., U.S.A.
GENERAL TECHNICAL INFORMATION AND DATA ON UHF TV ANTENNAS

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UHF TV PYLON ANTENNAS

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Typical UHF Pylon Antenna Installation
I. General Description of Non-Directional Type Antennas

A. THE "S" SERIES ANTENNAS USING ONE LAYER OFF-SET FEED

The physical characteristics of the "S" series antennas do not differ in any respect externally from the earlier center fed types. The salient difference is that the point of feed, instead of being at the center of the internal coaxial feeder, is displaced downward by one slot layer, or 3/2 wave lengths, from the geometrical center. At the UHF frequencies involved, this shift varies from approximately 37½ inches at Channel 14 to approximately 20 inches at Channel 83. Since this represents a small percentage of the overall length of the antenna, and since the radiation center has no specific definition for such an antenna of multiple sources of radiation and has been construed by implication to be the geometric center of the antenna, the geometric center is likewise considered the electrical or radiation center of an antenna employing this off-set feed.

B. "D" SERIES ANTENNAS HAVING TWO-LAYER OFF-SET FEED

The "D" series antennas similarly have no external physical differences from the earlier-center feed or the present "S" series antennas. The "D" antenna differs only in that they employ a point of feed off-set from the geometrical center downward by two layers of slots, or 3 wave lengths. This displacement ranges from approximately 75 inches at Channel 14 to approximately 40 inches at Channel 83. The radiation center, for the reasons outlined above, is considered to be the geometrical center.

II. Electrical Considerations in the Use of Off-Center Feed

To attain the desired high gain single lobe of suitable beam width directed at the horizontal and having minimum radiation in the minor lobes requires that the successive layers of slots be fed in phase. With such phase conditions the vertical radiation pattern will have minor lobes, however, accompanied by minima between the minor lobes which go to a theoretical zero value. In actual antennas where production tolerances are closely controlled, these nulls are minima which may in practice closely approach their theoretical value of zero. Thus the approach to a method of null fill-in becomes a matter of prime importance in obtaining signal distribution which will afford at least the minimum required field intensities over the desired service area. Ideally, the minima should be filled in to yield a smooth vertical pattern curve of proper shape, and having no lobes or points of minima, to achieve constant signal with varying distance over the area to be served. (See Fig. 1.) If the minima associated with the lower minor lobes are filled such that the average of these variations approaches such a curve, and the minima do not fall below the value required to attain minimum signal intensities, the minima fill-in requirements will have been obtained within the requirements of practice. Figs. 2, 3, and 4 show the ideal or cosecant field curve for three particular cases of antenna height and radii of service areas of constant field.

Feeding the various elements in phase but with an asymmetrical amplitude distribution is a practical method of approaching this minima fill-in requirement. This method is well adapted to series fed antennas where the radiated energy of a particular slot or layers of slots can be controlled by the degree of coupling to the feeder. Since the antenna consists of a discrete number of slot layers, the amplitude distribution must have a "stepped" power distribution rather than a smooth variation in distribution along the total aperture. The term "stepped" antenna arises from the plot of the radiated power per unit of distance along the aperture, as illustrated in Fig. 5. As indicated the coupling loops are set such that equal power is fed into the group or section of slot layers above the feed point and the group or section of slot layers below the feed point. The power radiated per element is then different in the top and bottom sections by the ratio of slot layers above and below the point of feed. In an eighteen-layer having two-layer off-center feed this results in an 11.7 division, thus the power density in the upper section has a ratio of 11/7 or 1.57 greater than the power density in the lower section.

Considering the upper and lower sections as two antennas, each having different patterns by reason of the different power densities, but fed with equal powers, as indicated in Figs. 5 and 6, it is evident that the minima and minor lobes will not occur at the same depression angles. Thus the resultant pattern will be one in which the minima cannot go to zero nor to values lower than the minima of either antenna, since the amplitudes are unequal at those depression angles and cannot produce complete cancellation even when in phase opposition.

Fig. 12 shows a calculated vertical pattern for a type TFU-24DM antenna, employing two-layer off-set feed and having no beam tilt, which evidences the benefits derived from such fill-in procedure. The use of beam tilt, to be discussed later, quite rapidly adds to the benefits derived from minima fill-in and does so to a much greater extent than with center-fed antennas. This is quite evident from the curve for the 24DM type with 1° of beam tilt, also shown on Fig. 12.

III. Use of Electrical Beam Tilt

The advantages of the use of beam tilt are well known and quite evident. Power directed in the horizontal plane at the antenna will serve no useful purpose in inducing
voltages at receiving antenna located near the earth at
or below the radio horizon. For this reason alone, it is
then evident that electrical beam tilt, which depress the
beam uniformly at all azimuth angles, should be used to
at least the extent that the beam is tilted to the horizon
or slightly below. Dependent upon the particular terrain
conditions, the distribution of population, the extent of the
population area from the transmitter and the vertical di-
rectivity pattern of the antenna considered greater values
of beam tilt are in virtually every case useful. The solu-
tion for particular cases of course lies in the careful
analysis of the above factors for a specific coverage
problem.

The use of minima fill-in contributes a slight reduction in
the power gain of the major lobe, by reason of the fill-in
process at the minima. However, this reduction in gain is
quite small, particularly in comparison of the penalties
in the major lobe to the great benefits derived at angles
below the major lobe. The use of beam tilt however does
require the suffering of greater reduction in gain at the
major lobe. However, for values of tilt commonly used
the penalties are not at all in proportion to the decided
benefits derived both for distant and close-in coverage.
The reduction in maximum lobe and horizontal power may
be read from Fig. 19. In addition to the apparent advan-
tage of displacing the power distribution from the horizon
or above, with the attendant waste of power contained
in the major lobe at and above the horizontal plane to
the areas where needed for receiver antennas, it is further
apparent upon examination of the several vertical pat-
terns that receivers at "medium" distances from the trans-
mitter will receive radiation from well up on the major
lobe curve rather than the area of lower relative field.

A further, and perhaps more important reason, for the
use of some electrical beam tilt is the rate at which minima
fill-in is accelerated. Fig. 13 shows the vertical pattern for
a 24DM antenna having zero beam tilt and 1° beam tilt.
The extent of fill-in for the same antenna when tilted is
readily observed. This may likewise be seen in examining
the zero and 1° tilt patterns for the TFU-21DL in Fig. 10
and the zero and 1° tilt patterns for the TFU-27DH in
Fig. 18.

Similarly, a comparison of the present one layer off-
set types TFU-21BL, TFU-24BMS, and TFU-27BHS for un-
tilted and tilted conditions may be examined by reference
to Figs. 7, 11, and 15.

It is apparent from an examination of the "D" type
antennas for the respective groups of channels that con-
siderable benefit is derived in the area of depression
angles of common interest to every installation, down to
about -6°. In Fig. 20 is shown the calculated pattern for
a 24DM with the ideal or cosecant field curve from
Fig. 3. The average of the calculated pattern is in close
agreement with the ideal curve, thus a real improvement
toward the condition of constant field versus distance for
the close-in area is obtained.

Beam tilt is accomplished rather simply in these antennas
by the simple expedient of displacing the entire harness
upward by a small distance. The shift amounts to only
a few inches and may be accomplished readily even after
erection of the antenna upon the tower. When shifted, the
upper section acquires a phase lead over the lower sec-
tion. To determine the distance to be shifted for a given
value of beam tilt the curves of Fig. 21 are used. From

this curve is read the phase difference 2δ. This value may
then be used in the equation:

\[ d = \frac{\delta}{360} \times 11802 \]  

\[ \delta = \frac{2d}{f} \]

When \( d \) = Shift in inches  
\( f \) = Frequency in mc

to determine the shift distance in inches. Suggested meth-
ods of mechanically accomplishing the harness shift are
described in the instruction book for these antennas.

IV. Horizontal Radiation Pattern

Antennas of this type have a horizontal pattern circular
within 0.5 db. The theoretical limit of circularity for 3-slot
layers rotated 60° is 0.02 db maximum to minimum ratio.

The effect of operating two such antennas in close pro-
ximity, as on a common tower platform, has been studied
to a limited extent. Further studies and measurements are
in process with respect to this mode of operation as well
as to investigate the effects of tower members on the
horizontal pattern when mounting such antennas internally
in a tower structure or closely adjacent to a tower as in
side mounting, as might be done with several antennas on
a common supporting tower. Figs. 22, 23, and 24 show
the measured horizontal patterns for a model antenna
having a cylinder of comparable dimensions in the pres-
ence of the antenna at different separations.

It may be concluded that separations on the order of
5 wavelengths will not cause variations in horizontal field
pattern circularity in excess of about 2 db. Figs. 25 and
26 show the effect on the horizontal radiation pattern of a
UHF antenna when mounted internally to a supporting
tower.

V. Directional UHF Antennas

Figs. 27 and 28 show the horizontal field radiation pat-
terns for two types of UHF directionals which readily lend
themselves to manufacture and which will probably be use-
ful for the majority of the conceivable installations which
would benefit from a directional pattern.

Fig. 27 is the pattern for a single slot per layer antenna,
the layers having the same slot dimensions and spacings
as in the non-directional antennas but with the slots col-
linear. Calculated and measured model curves are shown.

Fig. 28 shows the calculated and a measured model
pattern of a directional antenna having two slots per layer
spaced diametrically opposite.

The application of directionals must be limited to within
the requirements of the 10 db maximum variation limit.
Shaping of patterns within this limit may be assisted by
choice of the diameter of the radiating pipe, phasing of
the slot layers, and small angular rotation of selected slot
layers. Methods of null fill-in and beam tilt as applied to
non-directional antennas may be similarly applied to direc-
tional types to obtain the desired effects of control of the
vertical directivity pattern.

VI. Mechanical Specifications

Fig. 29 is a specification sheet for the various UHF an-
tennas currently produced. Table 1 lists the appropriate
mechanical parameters by channels associated with the
dimensions on the specification sheet.

Figs. 30, 31 and 32 show the tower mounting platen re-
quirements for the antenna flange furnished with each of
the three pipe sizes used with the various types of antennas.
### UHF Television Pylon Antennas

<table>
<thead>
<tr>
<th>Type</th>
<th>Sections</th>
<th>Channels</th>
<th>Relative Gain</th>
<th>Gain In DB</th>
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<td>14-30</td>
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<tr>
<td>TFU-3BM</td>
<td>2</td>
<td>31-50</td>
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<td>51-83</td>
<td>3</td>
<td>4.77</td>
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<td>7.78</td>
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<tr>
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<td>6</td>
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<td>9.54</td>
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<td>13.80</td>
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<td>51-83</td>
<td>27</td>
<td>14.31</td>
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<tr>
<td>TFU-27DH</td>
<td>18</td>
<td>51-83</td>
<td>27</td>
<td>14.31</td>
</tr>
</tbody>
</table>

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**Amplitude of Signal**

**CURVE A:** \( F(\alpha) = \frac{\sin \phi}{\phi} \); \( \phi = \frac{2\pi w}{\lambda} \sin \alpha \)

**CURVE B:** \( F(\alpha) = \csc \alpha \)

**FIGURE-1**

Ideal Curve to Yield Constant Field Strength versus Distance
FIGURE 2
VERTICAL FIELD PATTERN
FOR
CONSTANT FIELD STRENGTH
TO TWO MILES
FOR
ANTENNA HEIGHT OF 200 FT.

RELATIVE FIELD

DEGREES BELOW HORIZONTAL PLANE
FIGURE 3
VERTICAL FIELD PATTERN
FOR
CONSTANT FIELD STRENGTH
TO FOUR MILES
FOR
ANTENNA HEIGHT OF 500 FT.
FIGURE-4
VERTICAL FIELD PATTERN
FOR
CONSTANT FIELD STRENGTH
TO SEVEN MILES
FOR
ANTENNA HEIGHT OF 1000 FT.
FEED POINT AT $\delta$ - EQUAL POWER TO EACH SECTION

Thus

\[ \frac{b^2}{c^2} = \frac{a - \delta}{a + \delta} \]

**FIGURE - 5**
POWER DISTRIBUTION OF "STEPPED" ANTENNA

**FIGURE - 6**
"STEPPED" ANTENNA CONSIDERED AS TWO ANTENNAS
FIGURE- 7
CALCULATED VERTICAL PATTERNS
OF
UHF ANTENNA TYPE TFU 21 BLS
14 LAYERS DIVIDED 8-6 0°-TILT
AND
UHF ANTENNA TYPE TFU 21 BLS
14 LAYERS DIVIDED 8-6 1°-TILT
FIGURE 9
MEASURED VERTICAL FIELD PATTERN OF UHF ANTENNA TYPE TFZI38S 14 SECTIONS, CHANNEL 28 556 MC, 0° BEAM TILT DIVIDED 8:6

RELATIVE FIELD STRENGTH

ANGLE OF DEPRESSION, DEGREES

-14 -12 -10 -8 -6 -4 -2 0 2 4 6 8 10 12 14
FIGURE-10
CALCULATED VERTICAL PATTERNS OF
UHF ANTENNA TYPE TFU 21 DL
14 LAYERS DIVIDED 9-5 0°-TILT
AND
UHF ANTENNA TYPE TFU 21 DL
14 LAYERS DIVIDED 9-5 1°-TILT

RELATIVE FIELD

0°-BEAM TILT

1°-BEAM TILT

ANGLE OF DEPRESSION, DEGREES
FIGURE-11
CALCULATED VERTICAL PATTERNS
OF
UHF ANTENNA TYPE TFU 24 BMS
16 LAYERS DIVIDED 9-7 0°-TILT
AND
UHF ANTENNA TYPE TFU 24 BMS
16 LAYERS DIVIDED 9-7 1°-TILT

ANGLE OF DEPRESSION, DEGREES
FIGURE-13
CALCULATED VERTICAL PATTERNS
OF
UHF ANTENNA TYPE TFU 24 DM
16-LAYERS 10-6 DIVISIONS 0°-TILT
AND
UHF ANTENNA TYPE TFU 24 DM
16-LAYERS 10-6 DIVISIONS 1°-TILT

RELATIVE FIELD

0°-BEAM TILT

1°-BEAM TILT

ANGLE OF DEPRESSION, DEGREES
FIGURE-15
CALCULATED VERTICAL PATTERNS
OF
UHF ANTENNA TYPE TFU 27 BHS
18 LAYERS DIVIDED 10-8 0\(^\circ\)-TILT
AND
UHF ANTENNA TYPE TFU 27 BHS
18 LAYERS DIVIDED 10-8 1\(^\circ\)-TILT

RELATIVE FIELD

0\(^\circ\)-BEAM TILT

1\(^\circ\)-BEAM TILT

ANGLE OF DEPRESSION DEGREES
FIGURE 16
MEASURED VERTICAL FIELD PATTERN OF UHF ANTENNA TYPE T7U-27BHS.
18 SECTIONS DIVIDED 10°.
CHANNEL 55 718 MC 0-BEAM TILT.
FIGURE 17
MEASURED
VERTICAL FIELD PATTERN
OF
UHF ANTENNA TYPE TFU 27 BHS
18 SECTIONS DIVIDED 10-8
CHANNEL 55 718-MC
1.0° BEAM TILT

RELATIVE FIELD STRENGTH

ANGLE OF ELEVATION, DEGREES
FIGURE-18
CALCULATED VERTICAL PATTERNS OF
UHF ANTENNA TYPE TFU 27 DH
18 LAYERS DIVIDED II-7 0°-TILT
AND
UHF ANTENNA TYPE TFU 27 DH
18 LAYERS DIVIDED II-7 1°-TILT

RELATIVE FIELD

0°-BEAM TILT

1°-BEAM TILT

ANGLE OF DEPRESSION, DEGREES
Figure 20
Calculated vertical pattern of off center fed UHF antenna type TFU 24DM. 16 sections divided 10-6, 1.0° beam tilt. Power gain = 79% of standard untilted antenna.

Uniform field strength curve for antenna height 500 ft. to four miles.
HORIZONTAL FIELD PATTERN

UHF ANTENNA TFU 24 BMS

NEAR VERTICAL CONDUCTING CYLINDER

CYLINDER

ANTENNA

CH. 43 646 MC  CYL. DIA. = 8-IN
2\lambda SEPARATION

FIGURE-22
HORIZONTAL FIELD PATTERN
UHF ANTENNA TFU 24 BMS
NEAR VERTICAL CONDUCTING CYLINDER

CH. 43 646 MC CYL. DIA. = 8-IN
4 λ SEPARATION
HORIZONTAL FIELD PATTERN
UHF ANTENNA TFU 24 BMS
NEAR VERTICAL CONDUCTING CYLINDER

CH. 43  646 MC  CYL. DIA. = 8 - IN.
5\(\lambda\) SEPARATION

FIGURE-24
HORIZONTAL FIELD PATTERN
UHF ANTENNA TFU24 BMS
NEAR VERTICAL CONDUCTING STRIP

CH. 43  646 MC PLATE 10" WIDE
2\lambda SEPARATION

FIGURE - 26
HORIZONTAL FIELD PATTERN
SINGLE LAYER CARDIOID

FREQ. = 532 MC  8\(\frac{5}{8}\) O.D. PIPE
\[
\frac{D}{\lambda} = 0.388
\]
PRELIMINARY ENGINEERING DATA
UHF SLOTTED TELEVISION ANTENNAS

ELECTRICAL SPECIFICATIONS

Power Handling............................................10 kw up to 10,000 ft.

Maximum Ambient Temperature, at Full Power.............45° C.

Input Impedance.................................50 ohms, V.S.W.R. less than 1.1/1

Input Connection........Single 3½ UHF flanged coaxial line

Hor. Pattern Circularity..................................±0.5 db

MECHANICAL SPECIFICATIONS

Design Assumptions

- Max. wind velocity (½" rad. ice) 95 mph.
- Max. wind velocity (no ice) 110 mph. (50/30 p.s.f.).
  Tensile stress below 20,000 p.s.i.
- Actual wind velocity.
- Max stress on bolts 18,000 p.s.i.

Channels (approx.) ........................................14 to 30 incl. 14 to 30 incl. 31 to 50 incl. 51 to 83 incl.
Type Number ............................................TFU-21BLS TFU-24BLS TFU-24BMS TFU-27BHS
MI Number ............................................MI-19195 D.* MI-19195 A.* MI-19195 B.* MI-19195 C.*
Weight, (Pounds) ...........................................Varies with channel—See Table 1
A, Inches (diam.) ...........................................10¾ 10¾ 8¾ 6¾
B, Inches ...........................................37 to 32 37 to 32 32 to 28 30 to 25
C, Inches (bolt circle) .....................................15¼ 15¼ 13 10¾
D, Inches (diam.) ...........................................17¾ 17¾ 15 12½
E, Inches (bolt diam.) .....................................1½ 1½ 1 7¾
F, Number of Holes .........................................16 16 12 12
H, Feet ..................................................Varies with channel—See Table 1
H₁ All ..................................................H₂ + 1 ft.
H₂ (elect. ctr.) .............................................Varies with channel—See Table 1
R₁ (50/30 p.s.f.) No Ice ....................................Varies with channel—See Table 1
M, Ft./Lbs (Moment) (30 p.s.f.) .............................Varies with channel—See Table 1
Relative Gain ............................................21 24 24 27
G Top Cap Hole (diam.) ...................................9¾” 9¾” 7¾” 5¾”

* Note: Suffix number added to MI number indicates channel number.
TABLE I

PRELIMINARY UHF ANTENNA DATA
WEIGHTS, HEIGHTS, AND MOMENTS FOR FILING

<table>
<thead>
<tr>
<th>Channel No.</th>
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<th>$H$(Ft.)</th>
<th>Weight</th>
<th>$R_1$(Ft./Lbs.)</th>
<th>$M$(Ft./Lbs.)</th>
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$H_2$—Height to Electrical Center.
$H$—Overall Height.
$R_1$—Wind Load at 50/30 p.s.f.
$M$—Overturning Moment at 50/30 p.s.f.
TOWER TOP INSTALLATION DRAWING
FOR MOUNTING RCA TFU-27BH ANTENNA
(6 3/8" DIA. POLE)
1. 8 TAP-12 HOLES
   EQUALLY SPACED ON
   18 = 1/8 DIA BOLT CIRCLE

2. 12 BOLTS AND 12
   LOCK WASHERS
   SUPPLIED BY RCA

3. 2 LEVELING
   PLATES BY RCA

4. THROUGH HOLES
   MINIMUM 1 THOS IN TOP
   FLATE

5. TO CONFORM TO ETMA
   9.112 STANDARD FOR 3/8
   300 OHM TRANS. LINE

6. TOP SURFACE TO BE FLAT WITHIN 0.01
   CLEAN AND FREE FROM ANY FOREIGN
   MATERIAL.

7. PRIOR TO MOUNTING ANTENNA, TOWER TOP
   TO BE HORIZONTAL WITHIN 0.5 DEGREE
   WITH NO WIND DEFLECTION ON TOWER

8. TOWER TOP TO BE EITHER GALV.
   FIN 4054 UNIFORMLY WITHOUT
   LUMPS OR TO BE PAINTED
   WITH 3 COATS RED LEAD OR
   EQUIVALENT. BOLTS MOUNTING
   FLANGE AND LEVELING RINGS
   TO BE ASSEMBLED WITH CULKING
   COMPOUND USING ZINC
   CHROMATE BASE - PL.17

FIGURE - 31
TOWER TOP INSTALLATION DRAWING

FOR MOUNTING RCA TFU-21BL & TFU-24BL ANTENNA

(10 ¾ DIA. POLE)

TOP SURFACE TO BE FLAT WITHIN 0.01
CLEAN AND FREE FROM ANY FOREIGN
MATERIAL.

PRIOR TO MOUNTING ANTENNA, TOWER TOP
TO BE HORIZONTAL WITHIN 0.3 DEGREE
WITH NO WIND DEFLECTION ON TOWER.

TOWER TOP TO BE EITHER GALV.
PIN **054** UNIFORMLY WITHOUT
LUMPS OR TO BE PAINTED
WITH 5 COATS RED LEAD OR
EQUIVALENT. BOLTS, MOUNTING
FLANGE AND LEVELING RINGS
TO BE ASSEMBLED WITH CYCLING
COMPOUND USING ZINC
CHROMATE BASE - P.17

FIGURE - 32
Address all inquiries and orders to one of the field offices listed below. At each location you will find a broadcast equipment specialist who is anxious to help you with your problems.

522 Forsyth Building
Atlanta 3, Georgia

John Hancock Building
200 Berkley Street
Boston 16, Massachusetts

666 N. Lake Shore Drive
Chicago 11, Illinois

718 Keith Building
Cleveland 15, Ohio

1907-11 McKinney Avenue
Dallas 1, Texas

RCA Building
1560 Vine Street
Hollywood 28, Calif.

340 Dierks Building
Kansas City 6, Missouri

36 W. 49th Street
New York 20, New York

1355 Market Street
San Francisco 3, California

RADIO CORPORATION OF AMERICA
Engineering Products Department
Camden, N. J.