THE STANDARD PATTERN

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A method of mathematically producing a directional antenna radiation pattern, which encompasses the theoretical pattern, is used in the United States of America. The "standard pattern" (or "expanded pattern") as it is called, simplifies frequency allocation management and inherently allows operational tolerance for directional antennas. This paper discusses the evolution of the standard pattern, its practical aspects and the technical basis for its mathematical construction.

EVOLUTION OF THE STANDARD PATTERN

Over 2000 different directional antenna patterns are currently in use in the medium frequency broadcasting band in the USA. Extensive use of directional antennas allows a particular frequency to be used by stations in different geographical locations, thereby achieving spectrum efficiency while balancing received and created interference. Conversely, use of omnidirectional antennas by numerous stations on a frequency severly limits each station's potential service area. As a frequency is more heavily utilized, the directional pattern designer is forced to focus on radiation patterns requiring large arcs of low radiation or pattern control in many directions where stations are to be protected from interference. In many early directional antenna designs, power gain was the objective, with little regard for pattern shape in areas of low signal. However, as frequencies became more heavily loaded, attention shifted to protection of other stations, with gain becoming a secondary factor.

The earliest directional antenna patterns used in the USA were theoretical patterns, with the basis for pattern size left to the discretion of the designer. Determination of the pattern size was a difficult and time consuming task. After an antenna system was constructed, "proof" of proper performance was required by the Federal Communications Commission (FCC). Adjustment of a directional pattern to exactly duplicate the theoretical pattern was often difficult or impossible, and excessive radiation, of course, created a potential for interference.

In order to achieve a margin for operational tolerance most engineers added larger values of radiation to all or a portion of the theoretical pattern and called them Maximum Expected Operating Values (MEOV). This was permitted, provided interference was not caused to other stations. The MEOV became the basis for determining the presence or absence of interference. Thus, by adjusting and maintaining its antenna pattern within the MEOV, a station did not increase its interference potential to other stations. However, since MEOV was added to the theoretical pattern in a manner which did not always have a mathematical relationship to the pattern, computerization of allocation studies was effectively precluded. Although the MEOV concept somewhat simplified allocation studies, it requires those engaging in allocation studies to maintain a file of directional antenna patterns. In addition to the difficulty in keeping these pattern files current, there was the possibility for error when reading a radiation value from a graph.

With widespread use of computers and programmable calculators, it became obvious that the frequency allocation process could be greatly simplified if directional patterns, and their operational tolerances (MEOV), could be mathematically generated on a uniform basis. Although use of the theoretical directional pattern (without MEOV) would fulfill that goal, no provision could be made for actual adjustment of patterns or for day-to-day pattern variations — a problem discussed in the next paragraphs. As the result of study by the FCC and industry engineers, a pattern design concept evolved which was called the "standard pattern". The standard pattern, which has been received favorably by U. S. broadcasters and their engineers, became the vehicle for efficient management of frequency resources since it provides a mathematically generated radiation "envelope" large enough to contain the theoretical pattern, thereby permitting a consistent procedure for allocation studies and for operational tolerance.

PRACTICAL ASPECTS

Theoretical directional antenna patterns are developed mathematically by vector summation of the fields from individual elements in the directional antenna system. The fields are assumed to be produced by sinusoidal current distribution in the elements of the antenna system, perfectly conducting earth in the vicinity of the antenna system, and all system losses represented by a resistance in series with each element. Such ideal conditions rarely exist although, in most situations, the departure of a measured pattern from calculated is minor. Theoretical directional antenna patterns can be designed to have "zero" radiation (zero nulls) in certain directions: however, perfect cancellation of fields, which produces a zero null, is unattainable in practice.

Experience shows that most directional antennas exhibit some degree of instability. The instability results from a number of factors, among them: an inherently poor directional antenna pattern design, a poorly constructed antenna system, improper adjustment of the antenna system, adverse weather conditions, sources of external reradiation, rough terrain, etc. Some of these factors also prevent zero nulls from being achieved. The standard pattern concept therefore provides a radiation "envelope" which is generally large enough to contain pattern variations and anomalies caused by one or more of these factors[1], thereby achieving the two-fold objective of simplifying frequency allocation management by being computer adaptable and allowing for directional antenna operational tolerance.

MATHEMATICAL CONSTRUCTION OF THE STANDARD PATTERN

The standard pattern has the theoretical pattern for its mathematical basis, with the "size" of the

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[1] When those factors prevent proper pattern adjustment, a futher mathematical method of modifying the standard pattern, called "augmentation", can be used. Augmentation provides for the entire radiation envelope to be larger, or for expansion of the pattern over certain sectors, or a combination of both. An increase in radiation in any direction which is likely to cause objectionable interference is not permitted, however. Information concerning augmentation may be found in Section 73.152 of the FCC "Rules and Regulations", Volume III, March, 1980.

pattern determined in a uniform manner assuming a minimum loss of one ohm in series with each element. To the theoretical pattern is added a quadrature term, "Q", which provides primarily for "null fill" and consequent elimination of "zero nulls". Adding "Q" in quadrature (at right angles) to the theoretical value of radiation greatly magnifies its effect in the null areas. After adding the "Q" term, the entire pattern is enlarged by five percent. This latter increase coupled with directional array losses generally greater than the assumed one ohm per element, virtually assures that the major lobe of radiation falls within the standard pattern value.

The "Q" term is a value adopted after many years of experience in adjustment of directional antennas, and provides the lowest permitted radiation value which is believed achievable under most circumstances. Note that for a directional antenna pattern with nominal power of 1000 watts or less, the minimum permitted radiation is 10 mV/m at one kilometer. The use of "Q", therefore, provides a degree of assurance that low radiation values (which presumably provides interference protection to other stations) are likely to be achieved and maintained.

The standard pattern equation is:

$$E(\emptyset,\theta)_{std} = 1.05\left[\left\{E(\emptyset,\theta)_{th}\right\}^2 + Q^2\right]^{1/2}$$

where:

$E(\emptyset,\theta)_{std}$ is the inverse distance field at one kilometer which is assumed to be produced by the directional antenna.

$E(\phi,\theta)_{th}$ is the theoretical inverse distance field at one kilometer as computed using Equation (1) of Chapter 5/5*, except that the multiplying constant, K, is determined assuming a lumped loss resistance of one ohm at the current loop of each element of the array (or at the base if the tower is less than 90 degrees). The computation of $K_{(loss)}$ is detailed in Section 4.5 of Chapter 5/19*

Q is the greater of the following quantities:

$$0.025\ f(\theta)\ E_{rss} \quad \text{or} \quad 10\ f(\theta)\sqrt{P}$$

$f(\theta)$ is the vertical plane distribution factor for the shortest element in the array, Equation (2) of Chapter 5/5*

E_{rss} is the root-sum-square of the amplitudes of the inverse fields of the elements of the array in the horizontal plane and is computed as follows:

$$E_{rss} = K_{(loss)} \left[\sum_{i=1}^{n} F_i^{\,2} \right]^{1/2}$$

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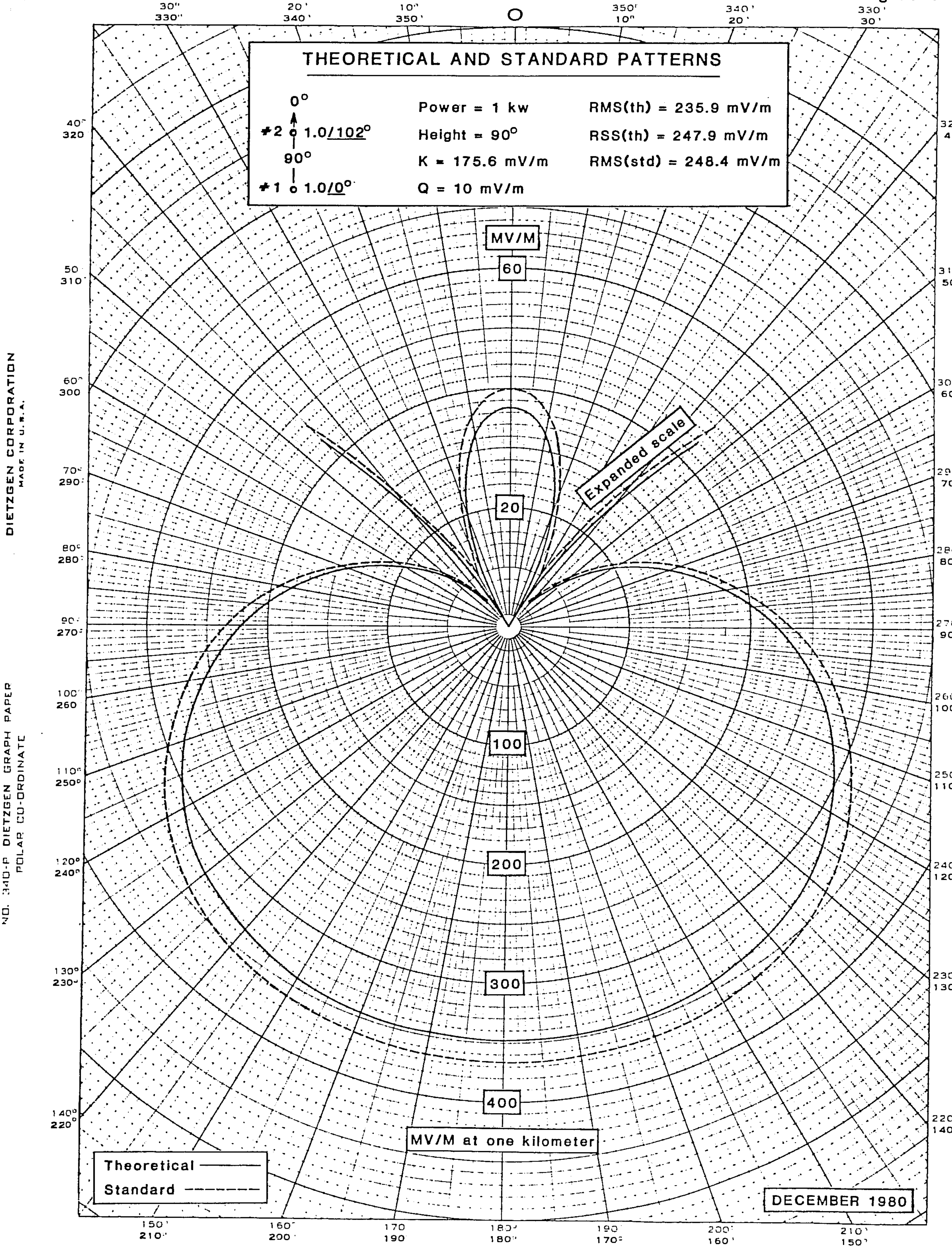
* Report to the Second Session of the Conference. Regional Administrative MF Broadcasting Conference (Region 2) First Session, Buenos Aires, 1980.

F_i is the field ratio of the i^{th} element

P is the nominal power in kilowatts and is restricted to a value of 1 or greater

Note that "Q" is the larger of two values which depend primarily on array design. In either case, the "Q" provides for "null fill", and adjustment tolerance. The attached Figure 1 graphically compares the theoretical and standard pattern for a two-element system. The "null fill" provided by "Q" is obvious. The major lobe radiation increase results from the five-percent factor which enlarges the entire pattern envelope.

Figure 1


THEORETICAL AND STANDARD PATTERNS
0°
#2 1.0/102°
90°
#1 1.0/0°
Power = 1 kw
Height = 90°
K = 175.6 mV/m
Q = 10 mV/m
RMS(th) = 235.9 mV/m
RSS(th) = 247.9 mV/m
RMS(std) = 248.4 mV/m
MV/M
60
20
100
200
300
400
Expanded scale
MV/M at one kilometer
Theoretical
Standard
DECEMBER 1980
0
30° 330°
20° 340°
10° 350°
350° 10°
340° 20°
330° 30°
40° 320
50 310°
60° 300
70° 290°
80° 280°
90° 270°
100° 260
110° 250°
120° 240°
130° 230°
140° 220°
150° 210°
160° 200°
170 190
180° 180°
190 170°
200° 160°
210° 150°
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