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Estimating the Gain of Yagi-Antennas from Chart Data

The author has described in (1) how the gain reduction due to sidelobes can be estimated for an antenna with a nearly rotational symmetrical polar diagramm. The comparison with practical measurements on a yagi antenna leads to a diagramm, which with easily obtainable values, gives a close approximation to the available gain.

1. BASIC THEORY

The familiar Kraus formula for antenna gain

$$G_i \approx \frac{4\pi}{\Phi_E \cdot \Phi_H} \qquad [1]$$

or for the angle in degrees and with reference to a dipole

$$G_d \approx \frac{25200}{\Phi_E \cdot \Phi_H} \qquad [2]$$

yields for an antenna whose half power or beamwidth Φ_E and Φ_H for both polarization planes are known, an upper limit for the gain. When the diagram has sidelobes suitable deductions are to be made.

In general, the main lobes and sidelobes are different for both diagram planes, the amateur is however, only interested in the directional characteristics of one plane, for horizontal polarization this is the E plane (the plane of the elements).

For a few types of antenna the relationship between E and H diagrams is known. One of these is the yagi antenna, superimposing (multiplication) the H diagram with a dipole characteristic results in a good approximation of the E diagram. The latter causes null points at ± 90° which in turn causes extensive cancelling of the sidelobes in the area of the null position; this leads to, for short and medium length antennas, a certain narrowing of the main lobe (from this it is clear that the often stated front/side ratio for the E plane is nonsense: a radiation in the direction of the elements can only arise from current in the boom or cable).

2. APPLICATION

From the previous basics it follows, that for a yagi antenna it is sufficient to know the important data characteristics of the diagram of one plane in order to determine the gain.

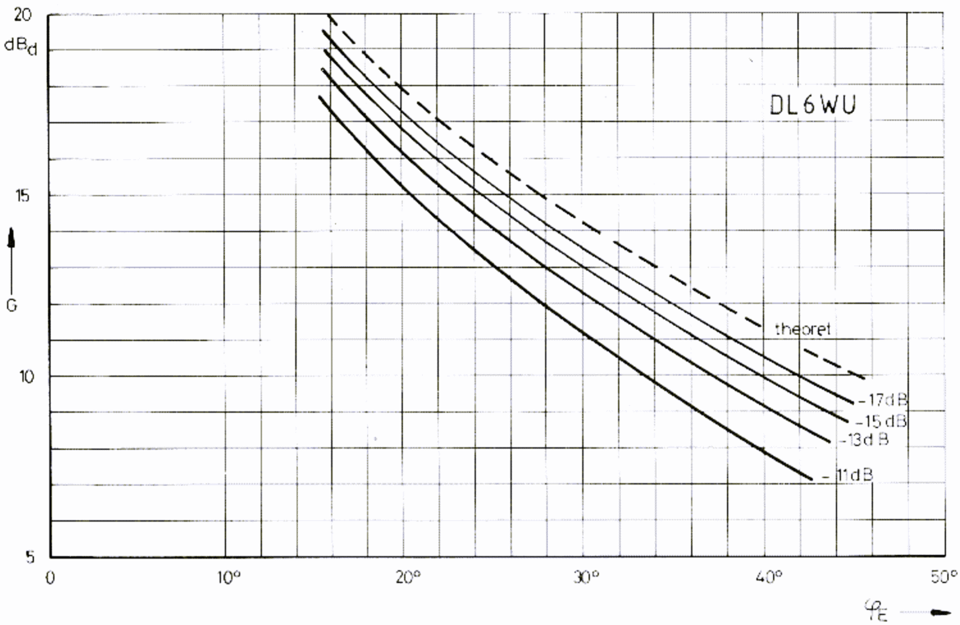

Fig. 1: Gain of yagi-antennas as a function of beamwidth Φ_E of the E plane and sidelobe damping

Fig. 1 shows dotted the theoretical gain of a loss free, sidelobe free antenna, as a function of the E beamwidth. The solid lines show the practical gains as a function of beamwidth for various degrees of sidelobe damping.

From this, the conclusion should not be drawn that an antenna with weak sidelobes generally has higher gain. For the same length of antenna decreasing the sidelobes increases the beamwidth of the main lobe. The gain remains nearly constant over a wide range. In spite of this it is normally preferable to choose the antenna with the least peaky sidelobes.

From **Fig. 1**, someone, able to measure dB's and angle degrees, can obtain a good estimate of the gain.

It must be stressed, that the diagram is only valid for single yagi antennas; not for arrays etc., since for these, completely different standards apply. Corrections for ohmic loss (skin effect) are normally unnecessary. The bases for this has been derived from test data, as well as from actual antennas. It goes without saying that drastic mismatching, unsymmetrical feeds etc. falsify the result. The almost amazing accuracy of the procedures has been confirmed by G. Schwarzbeck, DL1BU in (2).

3. PRACTICAL PROCEDURES

The antenna to be measured is aligned to a sufficiently strong and constant incoming signal (beacon), than the beamwidth is determined by rotating the antenna until the −3 dB-point is found, then rotate the antenna in the opposite direction

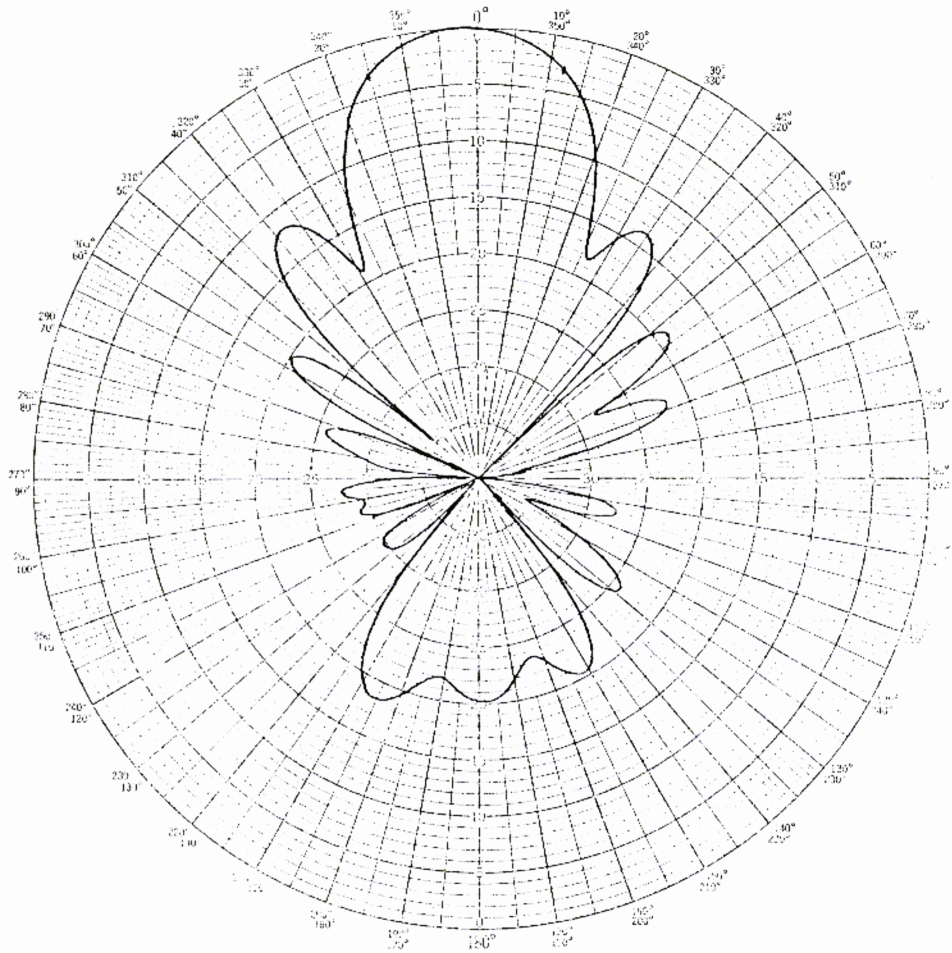

Fig. 2: Polar diagram of an 18 element yagi antenna measured on 1.10.1981 at 432.5 MHz

until the other −3 dB-point is found; the angle between these points is the required beamwidth. On the other side of the −3 dB-point the signal must quickly decrease, run through a pronounced minimum, then climb to a value usually lying 10 to 20 dB's under the maximum value. The signal difference is equal to the sidelobe attenuation.

All the following sidelobes must be smaller, at ± 90° there will be a deep null point. All backward lobes should be many dB's below the maximum gain of the antenna. An antenna with 14 dB gain must have at least 16 dB front to back ratio.

If the right and left sidelobes are very different, the field disturbance is caused either through reflection from buildings or the feed is unsymmetrical, eg. from the construction or the cable lead-in; small differences are averaged out.

When an exactly calibrated S meter is not available, a switched attenuator can be inserted in the signal path, and adjust for the same level. It is not possible to go below a certain minimum attenuator value, otherwise mismatching will falsify the results.

The found half power angle can now be easily examined: it is never bigger than half the angle Φ_{m1}, which is the angle between the first two minima. For shorter antennas it is noticeably smaller ($0.47 - 0.48\ \Phi_{m1}$ in order of 2λ long), from around 6λ long is almost exactly $0.5\Phi_{m1}$.

4. EXAMPLE

Fig. 2 shows the diagram of an 18 element antenna (Parabeam PBM18). The −3 dB-points lie at +12° and −15°, that means $\Phi_E = 27°$. The first minima lie at +27° and −29°, that means Φ_{m1} = 56°. The first sidelobes have sunk to around 12 dB and 14 dB respectively, the average sidelobe attenuation is therefore 13 dB. The front/back ratio comes to 19 dB. With these values transposed to **Fig. 1**, it gives a gain of 13.3 dB_d, the measured gain was 13.4 dB_d (dB_d gain ref. dipole).

The author has employed the diagram for many years to verify gain measurements and it immediately revealed any obvious errors in measurement.

5. LITERATURE

(1) Hoch, G.: YAGI-ANTENNAS-Principle of Operation and Optimum Design Criteria VHF COMMUNICATIONS Vol.9 Autumn 3/1977 · Pages 157 – 166

(2) Schwarzbeck, G.: Streifzug durch den Antennenwald cq-DL 52 (1981), H.3, S. 126 – 130