WinRFCalc
Simplify your work

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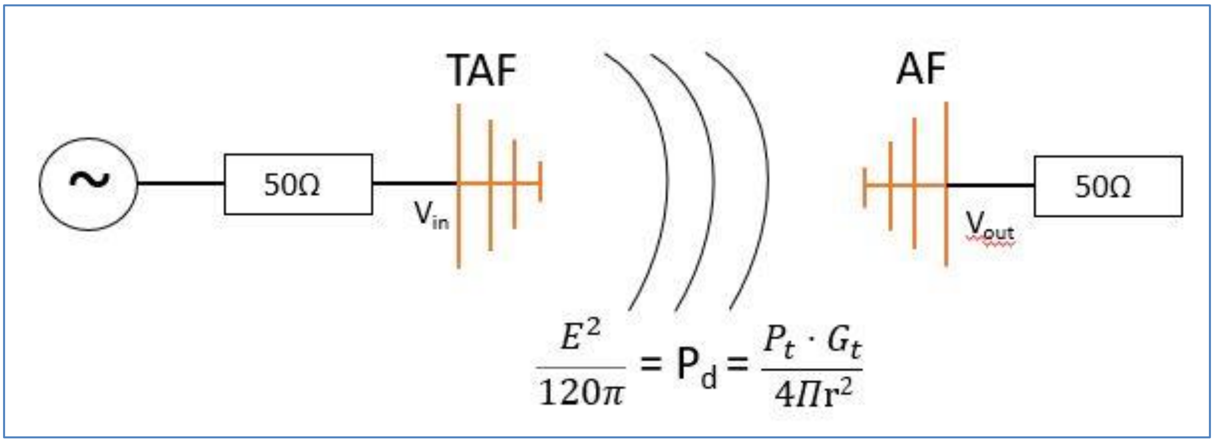
Introduction:

This app-note explains in detail the relationships between the Receive and the Transmit Antenna Factor, the latter better known as TAF. Please refer to the diagram below from where we explain how the common factor between the transmit and receive antenna, the Power density, is used to explain the transfer of energy between to two antenna's



The antenna factor, AF, describes the capability of an antenna to convert its exposure to an RF E-field into a voltage on the output terminated with 50 ohms. Therefore we can write for the antenna factor

$$AF = \frac{E}{V_L} \qquad (1)$$

Where in this formula

AF : Antenna factor
E : E-Field
V_L : Voltage on the antenna terminal

Another relationship between the incoming field and the power in the receiving terminating resistor is the Power Density Pd. The antenna has an effective aperture in m^2 showing how many square meter of antenna area is available to convert from field to terminal power

$$A_e = \frac{P_{out}}{P_d} \qquad (2)$$

Where in this formula

Ae : Effective Antenna Area in m^2
Pout : Power at the output terminal in Watts
Pd : The incoming power density in W/m^2

This can be rewritten as $P_{out} = P_d * A_e$

Another relationship between antenna performance factors Gain and Effective can be written as:

$$A_e = \frac{G_t * \lambda^2}{4 * \prod} \qquad (3)$$

where in this formula

Ae : *Effective Antenna Area in* m^2

Gt : *The numerical antenna-gain, equal to* $10^{\left(\frac{G_{dBi}}{10}\right)}$

λ : *Wavelength in meters*

The output power of the receive antenna is dissipated into an impedance Z. With V_L the voltage across this resistor, the power received by the antenna equals to:

$$P_{out} = \frac{Vl^2}{Z} \qquad (4)$$

The FAR field power density is given by $P_d = \frac{E^2}{120 \prod}$ (4)

With some substitution and rearranging we create the following relationship :

$$P_d = \frac{E^2}{120 * \prod}$$

$$P_{out} = \frac{Vl^2}{Z} \qquad P_{out} = P_d * A_e \qquad \frac{Vl^2}{Z} = \frac{E^2}{120 \prod} * \frac{G_t . \lambda^2}{4 . \prod}$$

$$A_e = \frac{G_t * \lambda^2}{4 * \prod}$$

Making some rearrangements for the antenna factor AF, we can conclude:

$$AF = \frac{E}{V_L} = \sqrt{\frac{480 * \prod^2}{Z * \lambda^2 * G_t}} = \frac{9.73}{\lambda * \sqrt{G_t}}$$

OR

$$AF = \frac{9.73}{\lambda * \sqrt{G_t}} = 19.8 - 20 * \log(\lambda) - 10 * \log(G_t)$$

Transmit Antenna Factor, TAF

Where the Antenna Factor is a number showing how efficient an antenna can covert an incoming power density to an output voltage, the TAF works the reverse way: power applied to the antenna creates a field.

We can start with:

$$TAF = \frac{E_{(\frac{dBV}{m})}}{V_{(dBV)}} \qquad (6)$$

where in this formula

E : *The field strength*

V : *The voltage across the antenna terminal*

The TAF is a number expressed in dB's. The TAF is derived from three relationships

1. The Friss transmission formula
2. Ohms law conducted
3. Ohms law in free space

1. <u>Friss transmission</u>

$$P_d = \frac{P_t * G_t}{4 * \prod * r^2} \qquad (7)$$

where in this formula

Pd : *The power density in W/m²*

Pt : *The transmit power in Watts*

Gt : *The numerical antenna gain*

R : *The distance from the antenna for Pd*

2. <u>Ohm's law on the antenna terminal</u>

$$P = \frac{V^2}{R} \qquad (8)$$

where in this formula

V : *The voltage on the antenna terminal (50Ω)*

P : *The transmit power in Watts*

R : *The impedance of 50Ω*

3. <u>Ohm's law in free space</u>

$$P_d = \frac{E^2}{120 * \prod} \qquad (9)$$

where in this formula

E : The field strength in V/m
Pd : The free space power density

Combining formula (7) and formula ()9 on the common factor Pd, power density.

$$P_d = \frac{P_t * G_t}{4 * \prod * r^2}$$

$$P_d = \frac{E^2}{120 * \prod}$$

$$\frac{E^2}{120 * \prod} = \frac{P_t * G_t}{4 * \prod * r^2} \Longrightarrow \frac{E^2}{} = \frac{P_t * G_t * 120 * \prod}{4 * \prod * r^2} \Longrightarrow E^2 = \frac{P_t * G_t * 30}{r^2}$$

Is resulting in the formula to calculate the E-field in front of an antenna based on input power Pt, numerical antenna gain Gt and the distance r from the tip of the antenna.

$$E = \sqrt{\frac{P_t * G_t * 30}{r^2}} \qquad (10)$$

From formula (8) we have

$$Pt = \frac{Vin^2}{R} \Longrightarrow Vin = \sqrt{Pt * R} \qquad (11)$$

The know ratio between the produced E-field and the power supplied to antenna, based on the TAF formula (6) gives

$$TAF = \frac{E}{V} = \frac{\frac{1}{r}\sqrt{30 * Pt * Gt}}{\sqrt{Pin * R}} \qquad (12)$$

With Pt = Pin we can simplify the above to:

$$TAF = \frac{1}{r}\sqrt{0.6 * Gt} \qquad (13)$$

Taking the 20 * log10 on both sides of formula (12) gives

$$TAF = \frac{1}{r}\sqrt{0.6 * Gt} \Longrightarrow TAF_{dB} = Gt - 2.22 - 20\log(r)$$