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Radio Range Model (Guidance manual)

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Introduction

The radio range model is an attempt to try to put some degree of light to the design criteria laid down for a radio communication system design.

The criteria of the radio transceiver design and the antenna system used, go to all play apart within the eventual success of any radio communication system design layout.

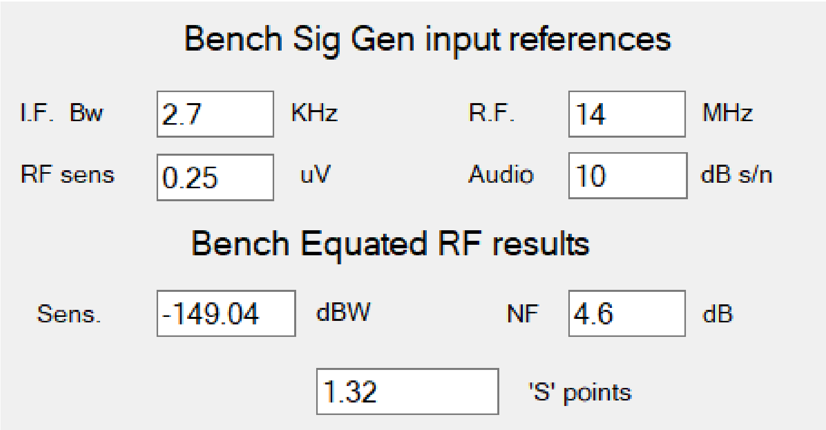
The radio signal propagation in any regard, has been a subject investigated by all radio communications technicians and engineers alike, include research scientists and all shortwave listeners and radio hams alike.

On the whole, radio signal propagation is a subject that is not only talked about a great length by radio hams and shortwave listeners, but also, a subject of much debate by the many professionals of the engineering craft of radio, mostly referred as radio the black art of distance communications, as well as the many applications related to topics of radio frequency engineering.

There is also much debate to the effects of any coaxial connector losses relating to any affect upon the radio propagation contact distance.

<u>Radio design principles</u>

Refer to the below image:



The above image bench tests are the reflection of the below image formulae:

```
' ************** theory RF sens based upon used Bw of radio ********************

BaseFloorVoltage = Math.Sqrt(4 * (1.38 * 10 ^ -23) * 290 * Bw * 50)
' voltage value equation of theoretical noise floor Power = 4*K*T*Bw
BaseFloorPower = (BaseFloorVoltage ^ 2) / 50
BasefloordBW = 10 * Math.Log10(BaseFloorPower)  ' convert into dBW
BasefloorINT = Int(BasefloordBW * 10) / 10      ' limit decimal places
BaseFloorValue = BasefloorINT

' ************** noise figure of radio based upon RF gen sens dBW and theory floor dB ********************

RxNoiseFigure = (BasefloordBW + AFdB) - radio_sens_measure_dBW
RxNoiseFigure = Int(RxNoiseFigure * -100) / 100
TextBox12.Text = RxNoiseFigure          ' string answer  ----- Radio Front-end Noise Figure
```

The signal meter calculations relate to as follows:

```
' ******************* sig gen test equated values ********************
' ***************  calculation of gen sens uV to dBW ********************

Dim radio_sens_measure_watts As Double = (RFsens ^ 2) / 50
Dim radio_sens_measure_dBW As Double = Int((10 * Math.Log10(radio_sens_measure_watts) * 100)) / 100
TextBox22.Text = Int(radio_sens_measure_dBW * 100) / 100

If Val(TextBox22.Text) >= -103 Then
    Dim dB_over As Double
    dB_over = Int((Val(TextBox22.Text) + 103) * 100) / 100
    TextBox9.Text = "9 +" & dB_over & "dB"
End If

If Val(TextBox22.Text) < -103 Then
    TextBox9.Text = Int((-157 - Val(TextBox22.Text)) / 6 * -100) / 100  ' S points of rx signal
End If
```

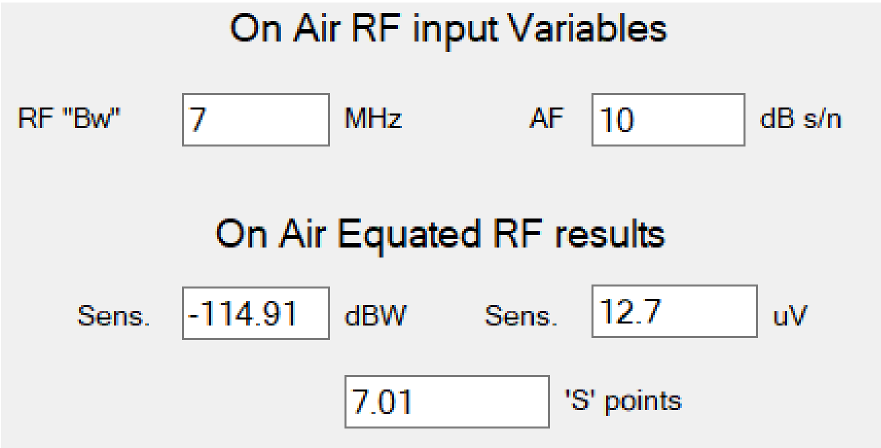
The above program coding listings, using visual basic, examines the radio performance, calculating the radio receiver noise figure, as well as calculating the minimum signal of the radio receiver to a required audio signal to noise ratio. The signal meter value is also listed to give the complete picture of an RF bench test performance summary.

The next stage is the calculated capability of the radio once connected to an on-air test. The difference here is that the RF bench test only refers the radio to an RF signal generator, whereas the noise within the RF signal generator test signal, is of a minimal value.

With the radio receiver now connected to an on-air antenna, the radio receivers front-end circuit bandwidth now comes into play, accumulating all the signal noise that the antenna can collect or pick up. It would be assumed, that the limiting bandwidth of the front-end circuit, would limit the bandwidth of antenna noise the radio would collect, and it is here where the radio receivers design can be affected to the overall on-air noise figure test of the radio receiver.

The RF signal generator noise floor bandwidth is limited, so the radio receiver would only experience the narrow noise from the signal generator, which is not the case when connected to an-air antenna. In days gone by, a parallel tuned circuit would be found within a radio circuit, namely within the front-end circuit design. Todays, this subject is more taken up by the use a high pass and low pass filters to limit the noise pick signal level, relating to the band plan in use.

However, considerations need to be taken as to the bandwidth differences between the parallel tuned circuit, and the use of a high pass and low pass filter combination.

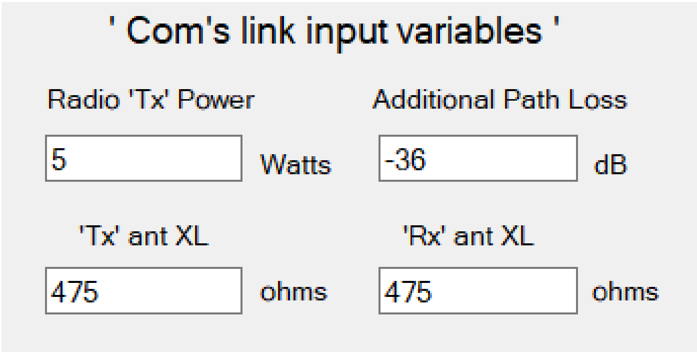


Notice the difference between the RF signal bench tests to the actual on-air experience.

```
Bw_front = Val(TextBox13.Text)
On_air_AFdB = Val(TextBox10.Text)
On_air_base_floor_volt = Math.Sqrt(4 * (1.38 * 10 ^ -23) * 290 * Bw_front * 10 ^ 6 * 50)
' voltage value equation of theoretical noise floor Power = 4*K*T*Bw
On_air_base_floor_watt = (On_air_base_floor_volt ^ 2) / 50
On_air_base_floor_dBW = 10 * Math.Log10(On_air_base_floor_watt)  ' convert into dBW
On_air_dBW = Int(On_air_base_floor_dBW * 100) / 100      ' limit decimal places

Dim gen_cal_Tx_dBW As Double = On_air_dBW + On_air_AFdB + RxNoiseFigure
gen_calculated_dBW.Text = Int((gen_cal_Tx_dBW) * 100) / 100
Dim sens_cal_watts As Double = 10 ^ (Val(gen_calculated_dBW.Text) / 10)
Dim sens_cal_volts As Double = Math.Sqrt(sens_cal_watts * 50)
gen_calculated_volts.Text = Int(sens_cal_volts * 10 ^ 6 * 100) / 100

If Val(gen_calculated_dBW.Text) >= -103 Then
    Dim dB_over As Double
    dB_over = Int((Val(gen_calculated_dBW.Text) + 103) * 100) / 100
    TextBox14.Text = "9 +" & dB_over & "dB"
End If

If Val(gen_calculated_dBW.Text) < -103 Then
    TextBox14.Text = Int((-157 - Val(gen_calculated_dBW.Text)) / 6 * -100) / 100  ' S points of rx signal
End If
```

The next question is how the antenna design contributes to the radio systems performance. This part also includes the radio transmitters powers output, for reference it is best looked at as the transmitters average power output, for reason that become clear later on.

The signal propagation losses, including the additional path losses, also come into play at this moment, allowing for terrain and signal propagation variables, such a signal lift of bad weather play.



Additional losses due to RF coax connectors losses can also be included within the additional path loss calculations.

The antenna specifications are listed as an inductive reactance, which is based upon the inductive reactance of a full wave wire antenna, irrespective of the radio signal frequency.

The effectiveness of an antenna design is then relative to the improvement or loss of the used antenna design, to the signal emissions or pick up relating to the full wave wire antenna performance.

It transpires, that the inductive reactance of a full wave antenna, is that of 475 ohms inductive reactance.

The dipole antenna design, has a centre collective impedance of 50ohms, used for radio communications, while for commercial radio, this collective impedance value is more of 75ohms terminal impedance.

The designed resonance of an antenna design, is thus the signal frequency upon which the antenna terminal impedance is matched to, be this 50ohms or 75ohms, or even 300ohms.

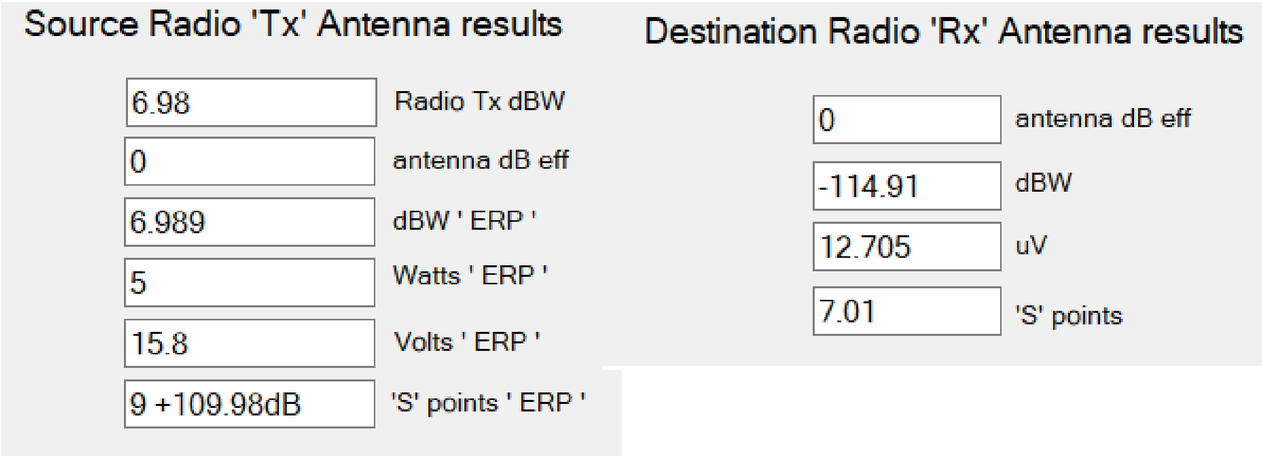
Relating to the dipole designed terminal impedance of 50ohms, each ¼ wave section delivers a signal source to the coax cable. The antenna sections to provide a 50ohm current source, each ¼ wave section would be twice that of the coax terminal impedance, or the dipole terminal impedance.

The ¼ wave sections would then be of a designed inductive reactance of 100ohms each, the combined parallel current source be then 50ohms effectively. The dipole antenna overall inductive reactance is then the combination of each ¼ wave section inductive reactance, 100ohms + 100ohms to a value of 200ohms.

To include that dipole antenna for the communications distance calculations, the 475ohms value of the antenna reactance would be replaced by the 200ohms value.

As the full wave wire has a full signal emission of collection, the dipole with its 200ohms collective reactance, would inhibit a reduced signal performance over the full wave wire antenna. The calculated difference of the dipole antenna is a 7·5dB reduction of antenna performance levels, relating to the full wave wire antenna.

The below image expresses these points of antenna effectiveness for a full wave wire:

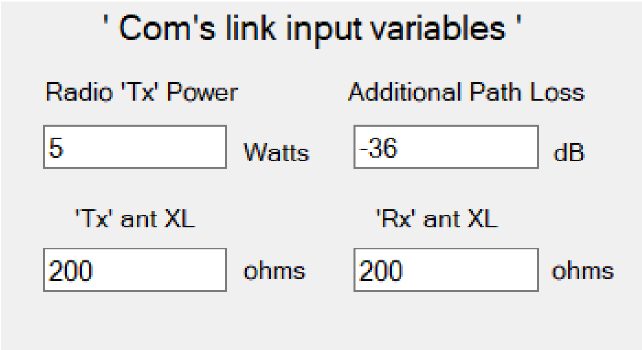


The visual basic program code for this is illustrated below:

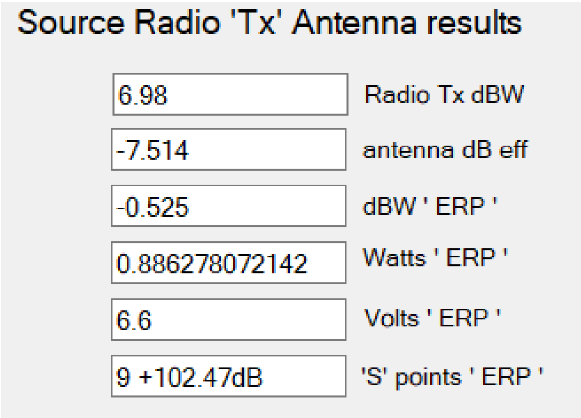
```
Dim Rx_ratio As Double

Rx_ratio = ant_eff_percentage_ant_Rf_set_Rx / 475

Dim Rx_ant_volt As Double

Rx_ant_volt = Rx_ratio * 5

Dim Rx_ant_watt As Double

Rx_ant_watt = (Rx_ant_volt * Rx_ant_volt) / 50

dB_rx_gain = 10 * Math.Log10(Rx_ant_watt / 0.5)
dB_rx = Int(dB_rx_gain * 1000) / 1000
TextBox18.Text = dB_rx
Dim run_dB As Double = Val(gen_calculated_dBW.Text) - Val(TextBox18.Text)
TextBox5.Text = run_dB  ' Rx radio effect sensitivity

Dim Rx_mim_watt As Double
Rx_mim_watt = 10 ^ (run_dB / 10)  ' power of rx signal (radio + antenna)
Dim Rx_mim_volt As Double
Rx_mim_volt = Math.Sqrt(Rx_mim_watt * 50)
TextBox6.Text = Int(Rx_mim_volt * 10 ^ 6 * 1000) / 1000  ' voltage of rx signal, mim 1/1000uV

If Val(TextBox5.Text) >= -103 Then
    Dim dB_over_link As Double
    dB_over_link = Int((Val(TextBox5.Text) + 103) * 100) / 100
    TextBox7.Text = "9 +" & dB_over_link & "dB"
End If

If Val(TextBox5.Text) < -103 Then
    TextBox7.Text = Int((-157 - Val(TextBox5.Text)) / 6 * -100) / 100  ' S points of rx signal
End If
```

For a dipole antenna system, the “com’s link” values are some-what different:

Coms link:

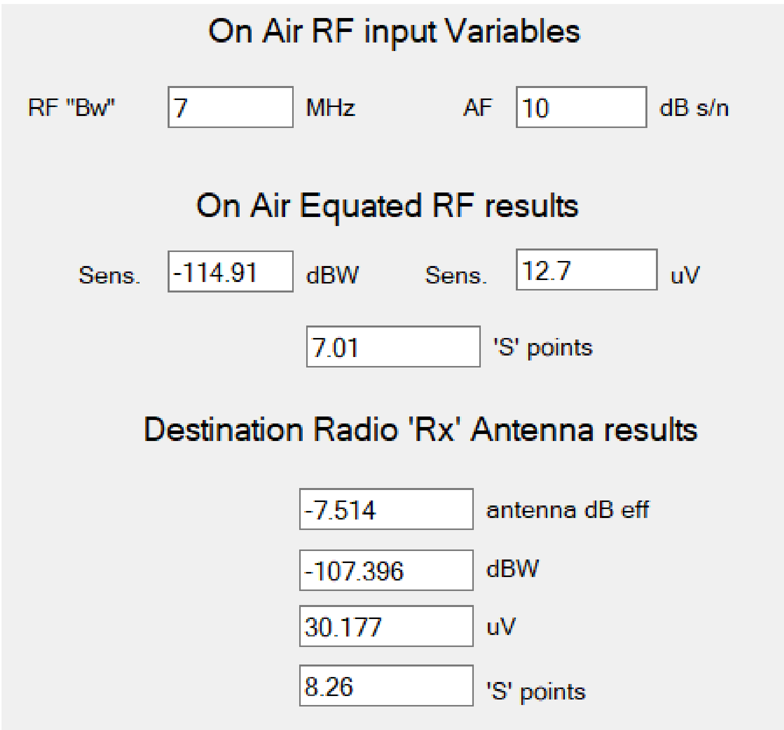


Transmitter on a dipole:



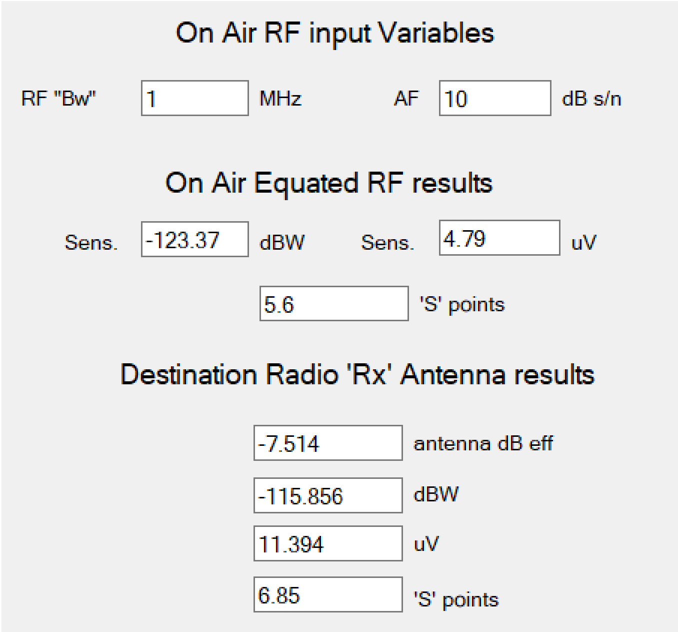
Notice the 7·5dB loss of the transmitter power output emissions via a dipole antenna, from 5watt transmitter terminal signal output, to a radiated 880mW from the dipole antenna.

The resulting effect upon the receiver is thus illustrated:



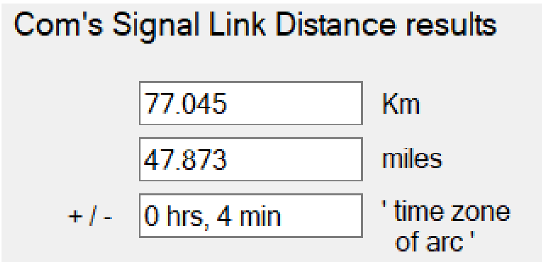
Notice the increased RF signal pickup required to supply the radio with a 12uV signal, for the receiver specifications.

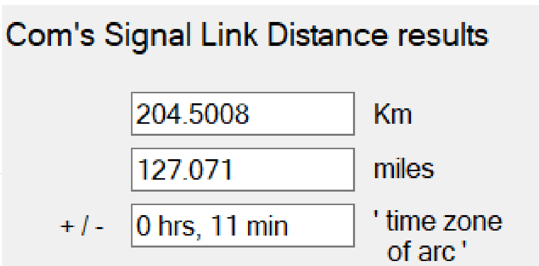
Now should a parallel tuned circuit be put into place within the radio front-end circuit design, to say a bandwidth of 1MHz down from the 7MHz as currently, the illustrated values are interesting to behold:



The radio receivers sensitivity is improved, from 12uV to 5uV, and the signal required for the dipole antenna is from 30uV to 11uV in essence.

The guidance of the propagation range between the standard receiver design and the use of an Tx/Rx relay switched parallel tuned circuit on Rx mode, is also quite interesting.





The top com's image is of the 7MHz front end bandwidth design, while the lower image is of the parallel tuned circuit of 1MHz additional filtering.

Each doubling of the signal wavelength travelled distance is a 6dB drop. This can be explained by the following. If a 20m band signal travels two wavelength, then at the end of the two wavelengths, the signal will be 6dB down. At four wavelengths, the signal is 12dB down, and at 8 wavelengths, the signal is 18dB down, and have travelled 160m in distance at 8 wavelengths.

On the 2metre band, the 8 wavelengths would be just 16 metres distance at 18dB down.

The signal propagation is then relative to the wavelength of the transmission signal to as the distance travelled for a 18dB down signal at the Rx end.

In addition to this, is the impedance found by a radio signal to its travel which is relative to the radio frequency wavelength.

Below are the calculation format for the com's link budget calculations:

```
Dim Wave_length As Double
Wave_length = 300 / (Val(freq_test.Text))

' Dim radio_emf_dBW As Double = Val(TextBox5.Text)   ' dBW of rx signal (radio + antenna)

Dim travel_Path_loss_dB As Double
travel_Path_loss_dB = (tx_budget_dB - run_dB) + path_loss_dB

Dim sq_law_factor As Double
sq_law_factor = travel_Path_loss_dB / 6

Dim m_value_distance As Double
m_value_distance = Wave_length * (2 ^ sq_law_factor)

Dim KM As Double
KM = (m_value_distance / 1000)
Dim KM_range As Double
KM_range = Int((KM) * 10000) / 10000
TextBox19.Text = KM_range

Dim miles_km_scale As Double = 3461.34 / 5570.48  ' london - new york = 3,461.34 miles / 5570.48 km

Dim miles As Double
miles = Int((KM_range * miles_km_scale) * 1000) / 1000
TextBox20.Text = miles

Dim Globe_cir As Double = 26738
Dim km_hour_arc As Double = 1114  ' earth rotation = 1114 Km/hour of arc
Dim range_hour_arc As Double = (KM / km_hour_arc)
Dim range_minutes_arc As Double = ((range_hour_arc) - Int(range_hour_arc)) * 60

TextBox8.Text = Int(range_hour_arc) & " hrs, " & Int(range_minutes_arc) & " min"
```