Installation of the radio monitoring system at Yebes observatory

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YebeS

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Revision history

Version	Date	Author	Comments
1.0	13.07.2016	D. Cordobés	First version
1.1	15.07.2016	José A. López-Pérez	Some comments added

Contents

1 System description

A radio monitoring system has been recently installed at the roof of the *Centro Astronómico de Yebes* (CAY) lab and office building on June 2016, with WGS84 coordinates 40° 31’28.50” N / 03° 05’ 18.95” W. Its purpose is to measure the amount of radio frequency interfering (RFI) signals that reach the observatory site. The system is capable of monitoring signals from 1 to 40GHz, with horizontal or vertical polarization, rotating from 0 to 360° in azimuth, at 5° per second, and -4.5° to +94.5° in elevation, at 2° per second.

The system is composed of the following equipment:

- Rohde-Schwarz AC090 SHF Directional Antenna System, which is a 0.9 m in diameter parabola.
- Rohde-Schwarz HL024S7, which consists of a crossed log-periodic antenna, working as the feed for the parabola, and a broadband preamplifier. It covers the 1 - 18 GHz band.
- Rohde-Schwarz AC308R2 SHF directional antenna with preamplifier, covering the 18 - 26.5 GHz band. It is a 25 cm in diameter parabola.
- Rohde-Schwarz AC308R3 SHF directional antenna with preamplifier, covering the 26.5 - 40GHz band. It is a 25 cm in diameter parabola, too
- Wilhelm Winter antenna rotator
- Rohde-Schwarz GX300 & GV300 control unit for positioning and selecting the antenna, and its associated frequency band, and its polarization. It can be controlled via serial RS-232C or RS-485, alternatively.

This system was donated by the Spanish *Dirección General de Telecomunicaciones y Tecnologías de la Información* to Yebes Observatory, where it has been restored and installed as mentioned above.

The complete detailed specifications can be found in **Appendix I**. The block diagram and the connections of the system is shown in **Figure 1** and the final assembly in **Figure 2.**

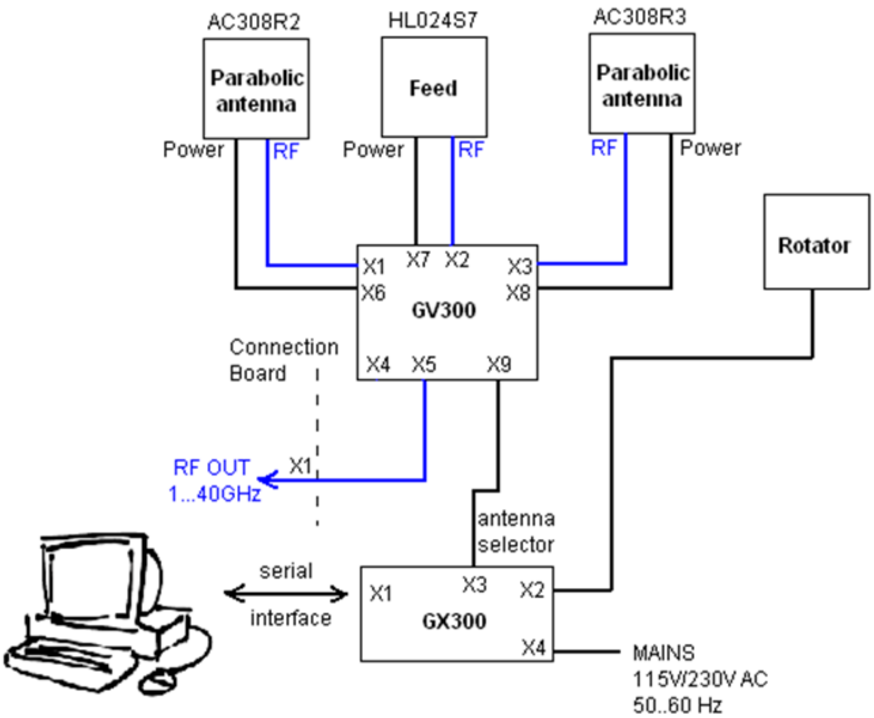

Figure 1: Block diagram of the system.

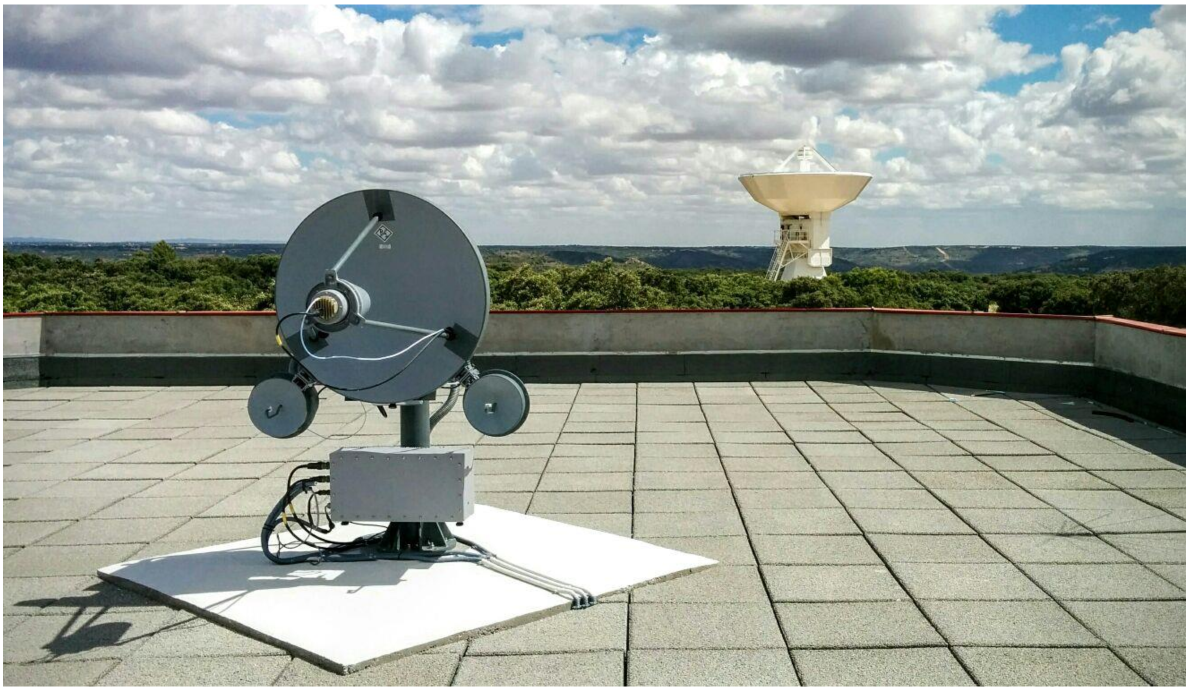

Figure 2: Installed radio monitoring system.

2 Cabling

The cabling of the system has been done between the receiver laboratory, in the first floor of the building, and the roof, consisting of:

- Power supply cable
- 3 wire RS485 cable
- RG-58 cable

The length of the cable is 36 meters, approximately. The host PC is connected to the RS-485 cable through a BlackBox© IC821A RS232 to RS485 converter.

The connection pin-out between the X1 connector of the GX300 module and the BlackBox is the following:

X1	BlackBox
Pin G (RS485+)	TDB+
Pin H (RS485-)	TDA-
Pin J (GND)	GND

3 Antenna control unit

The antenna is shipped with a Microsoft Windows controlling software called Accon, from Rohde & Schwarz (RS). According to RS, this software can be externally controlled through the Dynamic Data Exchange (DDE) Microsoft Windows protocol, which has been partially superseded by Object Linking and Embedding (OLE), but remains used for simple Windows interprocess communication tasks. Rohde & Schwarz also provides a list of DDE commands to which Accon responds.

The programming language chosen for building an application to interact with Accon has been Visual Basic, and as DDE is no longer supported in Visual Studio (the successor of Visual Basic), all the coding was done in Visual Basic 5.0. Additionally, the application implements UDP socket communication, so it can be remotely controlled through the LAN/Ethernet. The interface diagram of the software is shown in **Figure 3** and the graphical user interface of the CAY antenna control unit (ACU) application is presented in **Figure 4**.

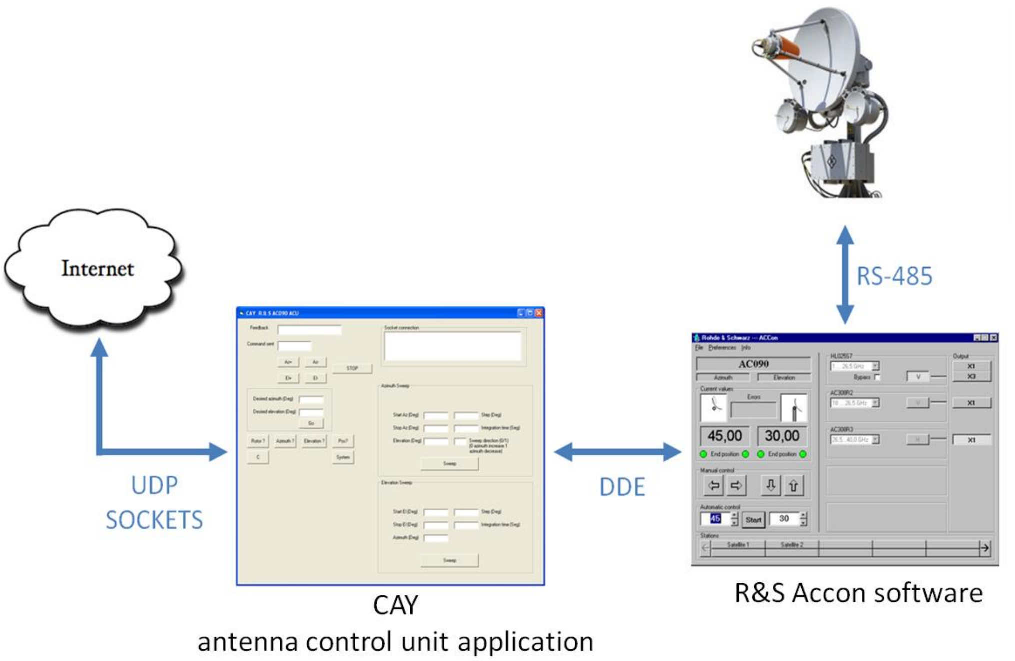

Figure 3: Software interface diagram.

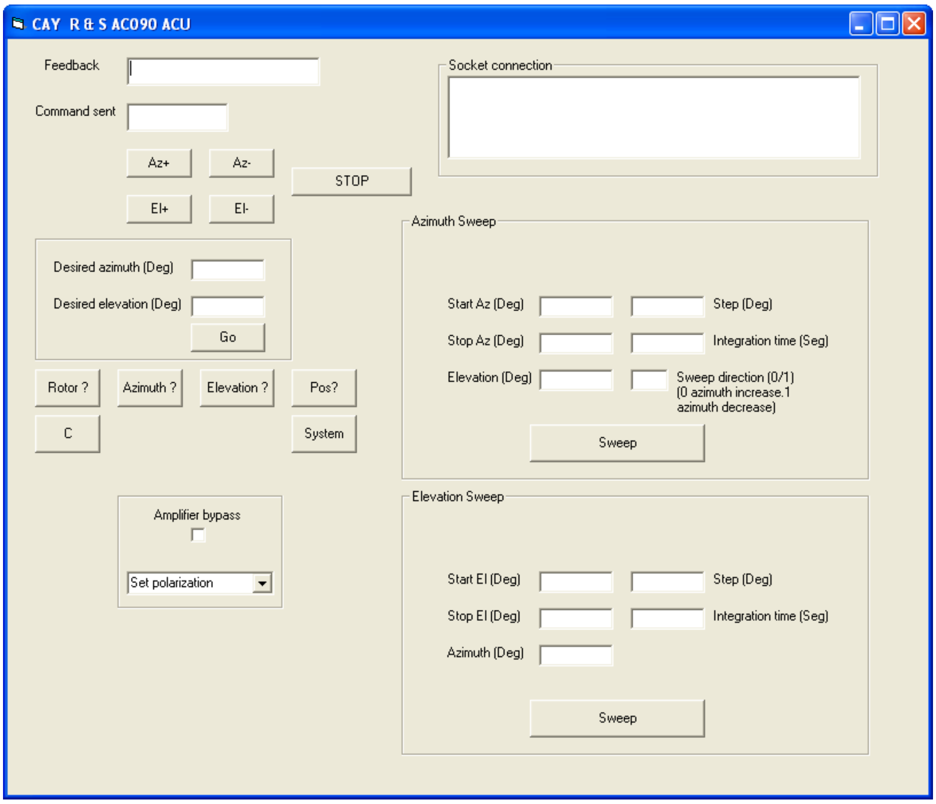

Figure 4: CAY R&S AC090 Antenna Control Unit

In order to be controlled by DDE, the Accon Sofware has to be configured according to **Figure 5**. Likewise, in the Visual Basic application there have to be two text boxes named *cmdSent* and *cmdReceived*, which will act as the output and input to the Accon software, respectively. The *linkmode* and *linktopic* fields of the Visual Basic graphical user interface have also to be defined the following way:

Linkmode: 1-Source

Linktopic: Form1

The Visual Basic application has to be compiled and built into an executable file named *ac090.exe*.

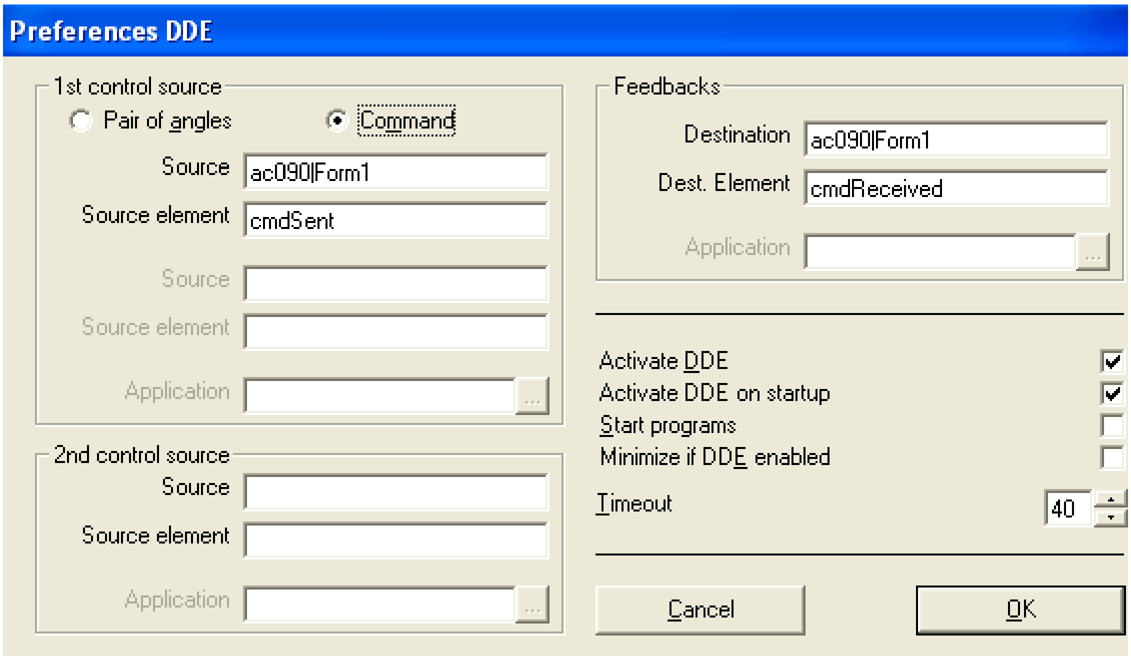

Figure 5: Accon DDE setup

The CAY antenna control unit software can be externally controlled through UDP datagram sockets. The list of commands is shown in **Table 1**. The code of the Visual Basic application is shown in **Appendix II**.

UDP COMMAND	MEANING
H	STOPS THE ROTATOR
QA	RETURNS AZIMUTH POSITION [AAA,AA]
QE	RETURNS ELEVATION POSITION [EE,EE]
QB	RETURNS POSITION [AAA,AA/EE,EE]
QFn	RETURNS DESIGNATION OF FEED n AS PLAIN TEXT. n possible values: 1 2 3
QS	RETURNS SYSTEM DESIGNATION AS PLAIN TEXT
QR	QUERY ROTATOR STATUS. Possible values: L: rotator is decreasing azimuth angle R: rotator is increasing azimuth angle U: rotator is increasing elevation angle D: rotator is decreasing elevation angle H: rotator is standing still The following combinations are possible: LD, LU, RD, RU
QL	QUERY STATUS OF THE LIMIT SWITCHES. Possible values: L: left limit switch triggered R: right limit switch triggered D: lower limit switch triggered U: upper limit switch triggered N: no limit switch triggered
C	CLEARS LAST FEEDBACK MESSAGE
E	TERMINATES THE PROGRAM
F1BX	BYPASS FEED 1 AMPLIFIER. X possible values: 0: don't bypass amplifier 1: bypass amplifier
F1PX	SETS THE POLARIZATION OF FEED 1. X possible values: V: Vertical polarization H: Horizontal polarization
SETPOS AAA,A/±EE,E If succesfull, returns antenna position [AAA,AA/±EE,EE] A: AZIMUTH E:ELEVATION	SETS THE ANTENNA POSITION AAA,A : Desired Azimuth [Deg]. Range 0° to 360° EE,E: Desired Elevation [Deg]. Range -4.5° to 94.5° Example: SETPOS 008,5/+50,6 takes the antenna to Azimuth 8,5° and Elevation 50,6°
AZ_SWEEP AAA,BBB,CCC, ±DD,EEE,F	Sweeps the antenna in azimuth with a constant elevation AAA: Start azimuth [Deg] BBB: Stop azimuth [Deg] CCC: Step azimuth [Deg] DD: Elevation [Deg] EEE: Integration time [sec] Range 0 to 999

If succesfull, returns antenna position [AAA,AA/±EE,EE] for each step of the sweep. A: AZIMUTH E:ELEVATION	F: Direction of the sweep. Can take the values 0 or 1: 0: Increasing azimuth 1:Decreasing azimuth Example: AZ_SWEEP 310,350,005,+45,002,0 moves the antenna from azimuth 310° to 350° in 5° steps with increasing azimuth, at an elevation of 45° and 2 seconds of integration time
EL_SWEEP ±AA, ±BB,CC,DDD,EEE If succesfull, returns antenna position [AAA,AA/±EE,EE] for each step of the sweep. A: AZIMUTH E:ELEVATION	Sweeps the antenna in elevation with a constant azimuth AA: Start elevation [Deg] BB: Stop elevation [Deg] CC: Step elevation [Deg] DDD: Azimuth [Deg] EEE: Integration time [sec] Range 0 to 999 Example: EL_SWEEP +35,+10,005,340,002 moves the antenna from elevation of 35° to 10° in 5° steps with an azimuth of 340° and 2 seconds of integration time

Table 1: UDP DDE commands

4 Antenna pointing correction

In order to know the azimuth offset correction that has to be applied to the antenna, a pair of radiolinks from known directions were used:

6.46 GHz coming from 27º azimuth (Horche)

5.85 GHz coming from 314º azimuth (Chiloeches)

Taking into account these azimuths, the offset correction for the antenna was derived (see **Figure 6**). The measurements are presented in Section 7.

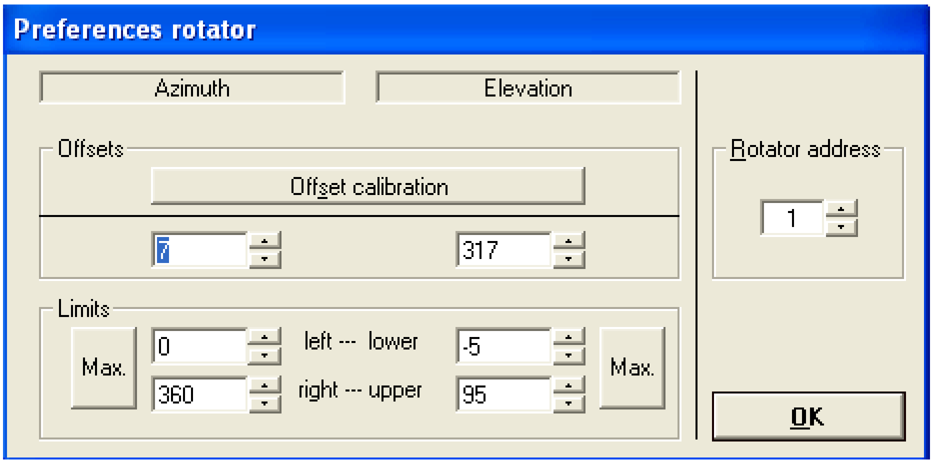

Figure 6: Accon pointing offset corrections

5 Accon configuration

In the following figures, it can be seen the system setup and how the Accon software has to be configured to communicate with the antenna:

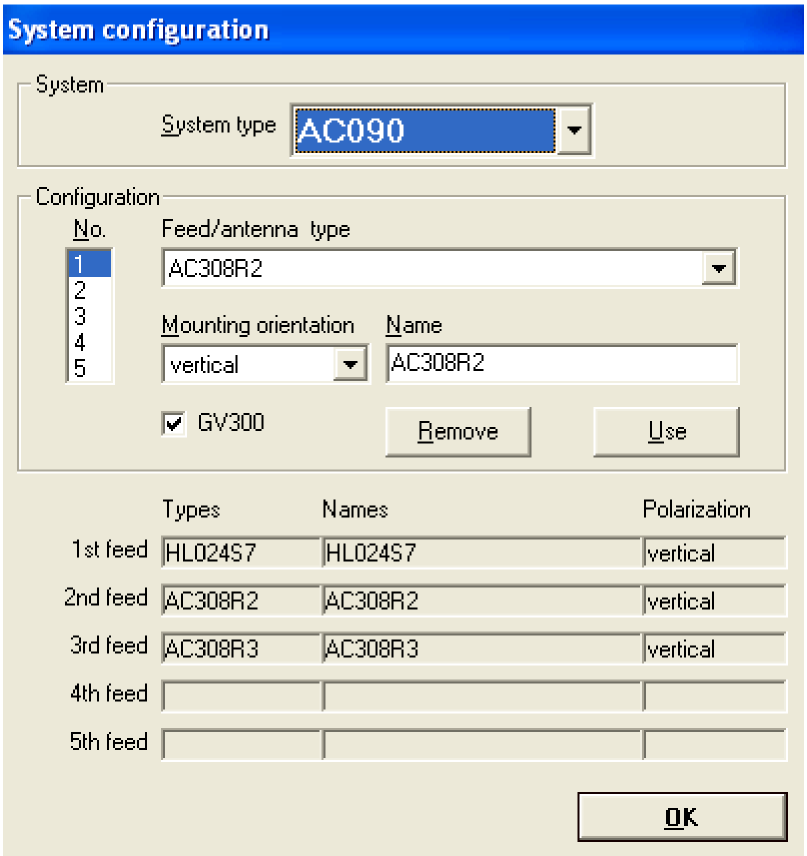

Figure 7: Accon system setup

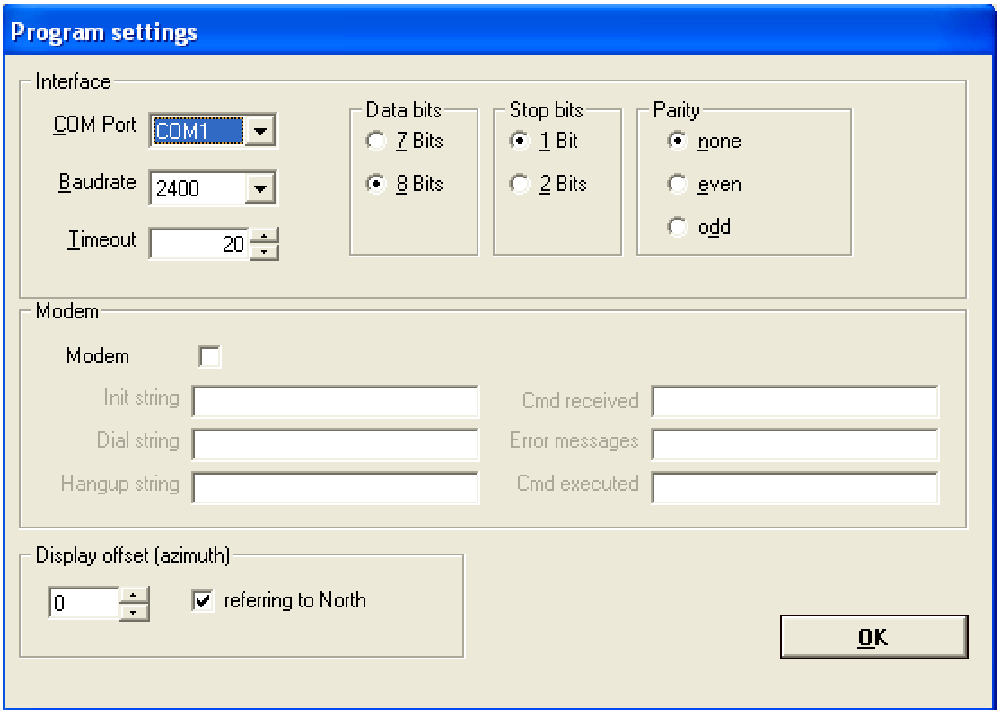

Figure 8: Accon serial communication setup

6 System integration

The Antenna Control Unit software and the Accon program have been installed in a HP DC7100 PC connected to a rack mountable Aaeon AMB screen. On top of them has been placed a spectrum analyzer which will receive and analyze the output signals from the antenna. The system has been mounted in a 19" rack (**Figure 9**).

Figure 9: System integration in rack

7 Preliminary measurements

In order to characterize the system and guess the antenna pointing offset correction to be applied (see Section 5), some measurements of already known radiolinks that reach the observatory site were made. The results are presented in **Figures 10** and **11**.

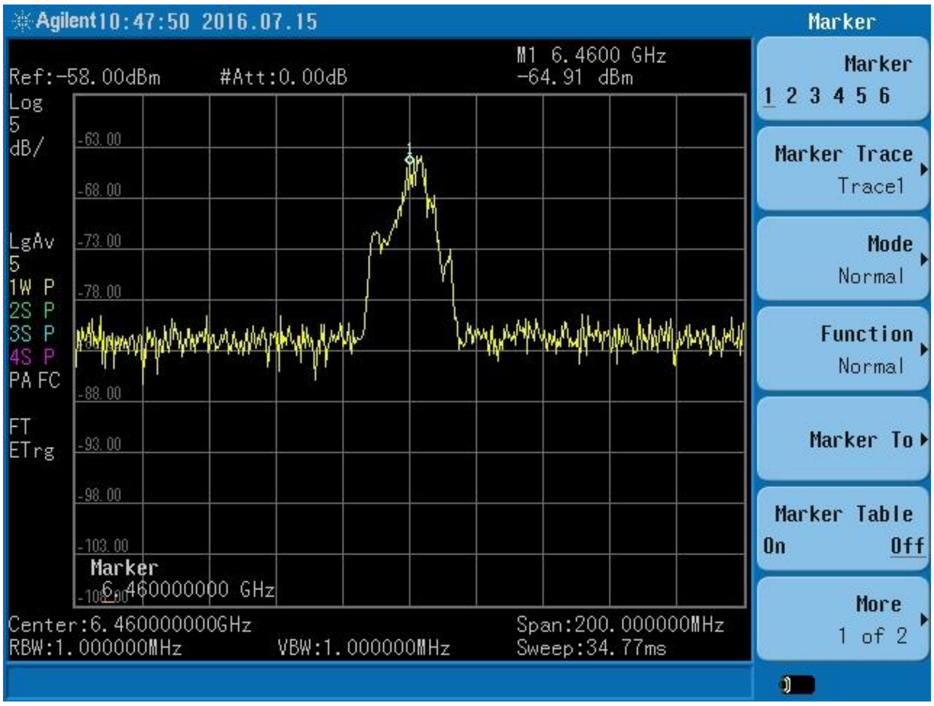

Figure 10: Radiolink coming from azimuth 27°

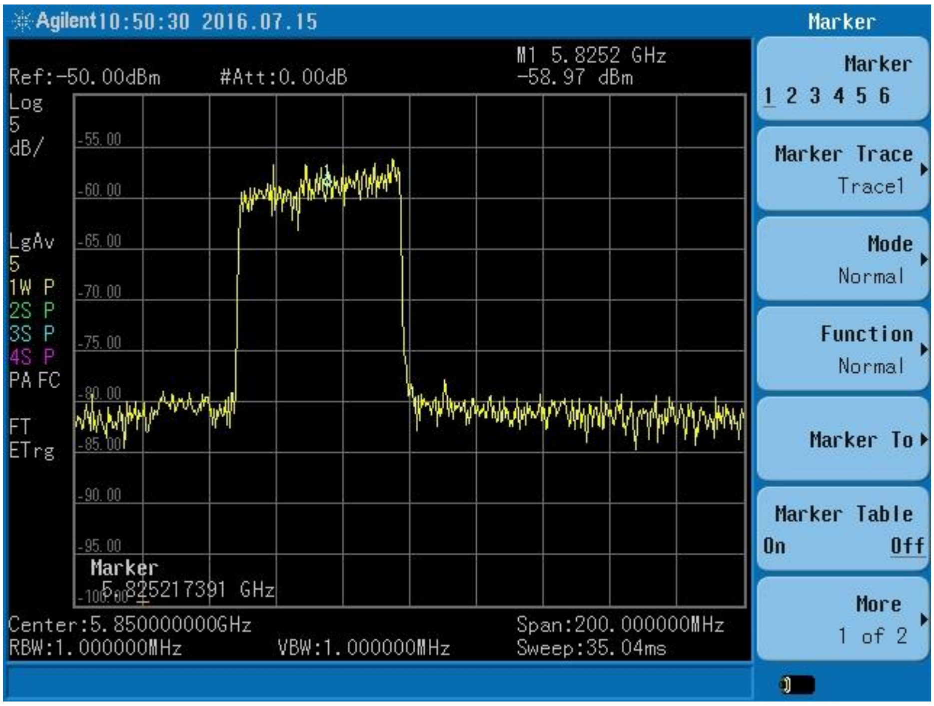

Figure 11: Radiolink coming from azimuth 314°

8 Conclusions

A radio frequency interference monitoring system has been set up on the roof of the *Centro Astronómico de Yebes* for the monitorization of disturbing radio signals, as described in this report.

The system is now ready to start operation, except for the installation of a low-loss coaxial cable to carry the antenna output signal from the roof to the spectrum analyzer in the laboratory, which is expected to be installed in the next few months. Then, the system will be fully operational and will start with RFI detection and monitoring.

Appendix I – System specifications

Antenna	**R&S®AC308R2**
Frequency range	18 GHz to 26.5 GHz
Polarization	H, V or 45 °, depending on installation
Nominal impedance	50 Ω
VSWR	<2
Gain	29dBi to 33 dBi
Half-power beamwidth	4.5 ° to 3 °
Reflector diameter	250 mm
Connector	K female
Preamplifier	
Gain	28 ±2 dB
1 dB compression point	≥+8 dBm
Noise figure	<3 dB
Power consumption	+15 V/0.2 A
Operating temperature range	–20 °C to +50 °C
Dimensions (diameter × length)	approx. 380 mm × 300 mm
Weight	approx. 2.5 kg

Antenna	**R&S®AC308R3**
Frequency range	26.5 GHz to 40 GHz
Polarization	H, V or 45°, depending on installation
Input impedance	50 Ω
VSWR	<2
Gain	33 dBi to 36 dBi
Half-power beam width	3 ° to 2 °
Reflector diameter	250 mm
Connector	K female
Preamplifier	
Gain	28 ±2 dB
1 dB compression point	≥+8 dBm
Noise figure	<4 dB
Power consumption	+15 V/0.2 A
Operating temperature range	–20 °C to +50 °C
Dimensions (diameter × length)	approx. 380 mm × 300 mm
Weight approx.	2.5 kg

Antenna	HL024S7
Frequency range	26.5 GHz to 40 GHz
Input impedance	50 Ω
VSWR	<2.5
Gain (without polarization switch/preamplifier)	>6 dBi
Noise figure	≤3 dB
Gain (active network – can be switched on)	26 dB ± 2 dB
1 dB compression point	approx. +8 dBm
Power supply	+15 V DC (max. 0.3 A)
Connector	SMA female
Control connector	10-contact, round, male
MTBF	>100.000 h
Operating temperature range	-30 °C to +55 °C
Dimensions (diameter × height)	
With radome	approx. 210 mm × 390 mm
Weight	approx. 1 kg

Appendix II – Antenna control unit source code

```
Private globalStop As Integer, socket_flag As Integer

Private Sub stopButton_Click()
   cmdSent.text = "H"
   globalStop = 1
End Sub

Private Sub qEl_Click()
   cmdSent.text = "QE"
End Sub

Private Sub qPos_Click()
   cmdSent.text = "QB"
End Sub

Private Sub qSys_Click()
   cmdSent.text = "QS"
End Sub

Private Sub cButton_Click()
   cmdSent.text = "C"
End Sub

Private Sub azDecrease_Click()
   cmdSent.text = "SL"
End Sub

Private Sub elIncrease_Click()
   cmdSent.text = "SU"
End Sub

Private Sub azIncrease_Click()
   cmdSent.text = "SR"
End Sub

Private Sub elDecrease_Click()
   cmdSent.text = "SD"
End Sub
Private Sub qRotor_Click()
   cmdSent.text = "QR"
End Sub
Private Sub qAz_Click()
   cmdSent.text = "QA"
End Sub
```

Appendix II – Antenna control unit source code

```
Private Sub CheckBox1_Click()

    If CheckBox1.Value = 1 Then
        cmdSent.text = "F1B1"
        WaitSeconds (2)
        cmdSent.text = "F1X1"
        WaitSeconds (2)
    Else
        cmdSent.text = "F1B0"
        WaitSeconds (2)
        cmdSent.text = "F1X1"
        WaitSeconds (2)
    End If
End Sub

Private Sub Combo1_Click()

   If Combo1.text = "V" Then
        cmdSent.text = "F1PV"
        WaitSeconds (2)
        cmdSent.text = "F1X1"
        WaitSeconds (2)
   ElseIf Combo1.text = "H" Then
        cmdSent.text = "F1Ph"
        WaitSeconds (2)
        cmdSent.text = "F1X1"
        WaitSeconds (2)
   End If

End Sub
Private Sub setPosButton_Click()

    Call Position_ant(enterAz.text, enterEl.text)

End Sub

Private Sub sweepAz_Click()

    Call Sweep_ant_az(startAz.text, endAz.text, fixedEl.text, stepAz.text, intTimeAz.text, AzDirection.text)

End Sub

Private Sub sweepEl_Click()

    Call Sweep_ant_el(startEl.text, endEl.text, fixedAz.text, stepEl.text, intTimeEl.text)

End Sub

Public Sub WaitSeconds(intSeconds As Integer)

  ' Waits for a specified number of seconds
```

```
 ' Params  : intSeconds      Number of seconds to wait

 Dim datTime As Date

 datTime = DateAdd("s", intSeconds, Now)

 Do
   DoEvents
 Loop Until Now >= datTime

End Sub

Public Sub Command_ant(angleAz As String, angleEl As String)

  Do While 1 'Wait until the rotator stops

      cmdSent.text = "C"
      WaitSeconds (1)

      cmdSent.text = "QR"
      WaitSeconds (1)

      If (StrComp(cmdReceived.text, "H") = 0) Then
         WaitSeconds (1)
         Exit Do
      End If

  Loop
  If globalStop = 0 Then
      cmdSent.text = "P" & "+" & angleAz & "/" & angleEl
      WaitSeconds (3)
  End If
  Do While 1 'Wait until the rotator stops

      cmdSent.text = "C"
      WaitSeconds (1)

      cmdSent.text = "QR"
      WaitSeconds (1)

      If (StrComp(cmdReceived.text, "H") = 0) Then
         WaitSeconds (3)
         Exit Do
      End If

   Loop

End Sub

Public Sub Sweep_ant_az(startAz As String, stopAz As String, elevation As String, stepAz As String, integTime As String, direction As String)
```

```
    Dim angleAz As String, i As Integer, stepAzint As Integer, ini_pos As Integer, end_pos As Integer

    cmdSent.text = "H"
    WaitSeconds (2)
    globalStop = 0
    i = 0

    stepAzint = CInt(stepAz)

    If Abs(CInt(startAz) - CInt(stopAz)) Mod CInt(stepAz) <> 0 Then

        If socket_flag = 1 Then
            sock_send.SendData "STEP_ERROR" 'The step doesn't match
        Else: MsgBox "STEP_ERROR"
        End If

        Exit Sub
    End If

    Do While 1

        cmdSent.text = "QA"
        WaitSeconds (1)
        ini_pos = CInt(cmdReceived.text)

        If direction = "0" Then
            end_pos = CInt(startAz) + stepAzint * i
        ElseIf direction = "1" Then
            end_pos = CInt(startAz) - stepAzint * i
        End If
        If end_pos < 0 Then
            end_pos = end_pos + 360
        ElseIf end_pos > 360 Then
            end_pos = end_pos - 360
        End If
        i = i + 1

        Call Position_ant(CStr(end_pos), elevation)

        WaitSeconds (integTime) 'Integration time

        If (globalStop = 1) Or (end_pos = CInt(stopAz)) Then Exit Do 'Stop the sweep if was called the H command or the sweep finished

    Loop

End Sub


Public Sub Sweep_ant_el(startEl As String, stopEl As String, azimuth As String, stepEl As String, integTime As String)

    Dim i As Integer, stepElInt As Integer, startElInt As Integer, stopElInt As Integer
```

```
    cmdSent.text = "H"
    WaitSeconds (2)
    globalStop = 0

    stopElInt = CInt(stopEl)
    stepElInt = CInt(stepEl)
    startElInt = CInt(startEl)

    If Abs(stopElInt - startElInt) Mod stepElInt <> 0 Then

        If socket_flag = 1 Then
            sock_send.SendData "STEP_ERROR" 'The step doesn't match
        Else: MsgBox "STEP_ERROR"
        End If

        Exit Sub
    End If

    If startElInt > stopElInt Then stepElInt = stepElInt * (-1)

    For i = startElInt To stopElInt Step stepElInt

        Call Position_ant(azimuth, CStr(i))

        WaitSeconds (integTime) 'Integration time

        If (globalStop = 1) Then Exit For 'Stop the sweep if it was called the H command

    Next i

End Sub

Public Sub Position_ant(angleAz As String, angleEl As String)

    Dim ini_pos As Double, end_pos As Double

    cmdSent.text = "H" 'Stop the antenna
    WaitSeconds (2)
    globalStop = 0

    cmdSent.text = "QA" 'Check in which azimuth we are
    WaitSeconds (1)
    ini_pos = CDbl(cmdReceived.text)
    end_pos = CDbl(angleAz)

    If CInt(angleEl) > 94.5 Then 'Elevation limits of the antenna: 94.5 and -4.5
        angleEl = "94.5"
    ElseIf CInt(angleEl) < -4.5 Then
        angleEl = "-4.5"
    End If
```

```
    ' If the antenna reaches 172 the limit switches activate so we have to reposition it manually, starting from 0º or 360º

    If ((ini_pos >= 0 And ini_pos <= 172) And end_pos > 172) Then
        Call Command_ant("0", angleEl)

        cmdSent.text = "SL"
        WaitSeconds (2)
        cmdSent.text = "H"
        WaitSeconds (2)

    End If

    If ((ini_pos <= 360 And ini_pos >= 172) And end_pos < 172) Then
        Call Command_ant("360", angleEl)

        cmdSent.text = "SR"
        WaitSeconds (2)
        cmdSent.text = "H"
        WaitSeconds (2)

    End If

    Call Command_ant(angleAz, angleEl)

    If socket_flag = 1 Then
        WaitSeconds (1)
        cmdSent.text = "QB"
        WaitSeconds (1)
        sock_send.SendData "[" & cmdReceived.text & "]"
    End If

End Sub

Private Sub Form_Load()
    Dim res

    sock_receive.LocalPort = 4001
    sock_receive.Protocol = sckUDPProtocol
    sock_receive.Bind sock_receive.LocalPort

    sock_send.Protocol = sckUDPProtocol
    sock_send.RemotePort = 4002

    res = Shell("accon.exe ", vbHide)
    socket_flag = 0


End Sub
```

Appendix II – Antenna control unit source code

```
Private Sub sock_receive_DataArrival(ByVal bytesTotal As Long)
    Dim str As String, posAz As String, posEl As String, startAz As String, stopAz As String, elevation As String, stepAz As String, intTimeAz As String, directionAz As String
    Dim startEl As String, stopEl As String, azimuth As String, stepEl As String, intTimeEl As String

    sock_receive.GetData str
    sock_receive.GetData str
    sock_receive.GetData str
    'MsgBox bytesTotal

    socket_flag = 1
    formulary.Enabled = False 'Disable the GUI
    rxSockTxt.text = "UDP connection socket from " & sock_receive.RemoteHostIP & vbCrLf & "Command received: " & str
    sock_send.RemoteHost = sock_receive.RemoteHostIP ' Send the data to the IP of the peer host

    If (StrComp(str, "H") = 0) Then
        cmdSent.text = "H"
        globalStop = 1 ' Stop the rotator
        WaitSeconds (0.3)

    ElseIf (StrComp(str, "QE") = 0) Then
        cmdSent.text = "QE"
        WaitSeconds (0.3)
        sock_send.SendData "[" & cmdReceived.text & "]"

    ElseIf (StrComp(str, "QB") = 0) Then
        cmdSent.text = "QB"
        WaitSeconds (0.3)
        sock_send.SendData "[" & cmdReceived.text & "]"

    ElseIf (StrComp(str, "QS") = 0) Then
        cmdSent.text = "QS"
        WaitSeconds (0.3)
        sock_send.SendData "[" & cmdReceived.text & "]"

    ElseIf (StrComp(str, "C") = 0) Then
        cmdSent.text = "C"
        WaitSeconds (0.3)

    ElseIf (StrComp(str, "SL") = 0) Then  'Use it with care as can activate limit switches
        'cmdSent.text = "SL"
        WaitSeconds (0.3)

    ElseIf (StrComp(str, "SU") = 0) Then  'Use it with care as can activate limit switches
        'cmdSent.text = "SU"
        WaitSeconds (0.3)

    ElseIf (StrComp(str, "SR") = 0) Then  'Use it with care as can activate limit switches
        'cmdSent.text = "SR"
        WaitSeconds (0.3)
```

```
ElseIf (StrComp(str, "SD") = 0) Then  'Use it with care as can activate limit switches
    'cmdSent.text = "SD"
    WaitSeconds (0.3)

ElseIf (StrComp(str, "QF1") = 0) Then
    cmdSent.text = "QF1"
    WaitSeconds (0.3)
    sock_send.SendData "[" & cmdReceived.text & "]"

ElseIf (StrComp(str, "QF2") = 0) Then
    cmdSent.text = "QF2"
    WaitSeconds (0.3)
    sock_send.SendData "[" & cmdReceived.text & "]"

ElseIf (StrComp(str, "QF3") = 0) Then
    cmdSent.text = "QF3"
    WaitSeconds (0.3)
    sock_send.SendData "[" & cmdReceived.text & "]"

ElseIf (StrComp(str, "F1B1") = 0) Then
    cmdSent.text = "F1B1"
    WaitSeconds (2)
    cmdSent.text = "F1X1"
    WaitSeconds (2)

ElseIf (StrComp(str, "F1B0") = 0) Then
    cmdSent.text = "F1B0"
    WaitSeconds (2)
    cmdSent.text = "F1X1"
    WaitSeconds (2)

ElseIf (StrComp(str, "F1PV") = 0) Then
    cmdSent.text = "F1PV"
    WaitSeconds (2)
    cmdSent.text = "F1X1"
    WaitSeconds (2)

ElseIf (StrComp(str, "F1PH") = 0) Then
    cmdSent.text = "F1PH"
    WaitSeconds (2)
    cmdSent.text = "F1X1"
    WaitSeconds (2)

ElseIf (StrComp(str, "QA") = 0) Then
    cmdSent.text = "QA"
    WaitSeconds (0.3)
    sock_send.SendData "[" & cmdReceived.text & "]"

ElseIf (StrComp(str, "QR") = 0) Then
    cmdSent.text = "QR"
    WaitSeconds (0.3)
```

```
        sock_send.SendData "[" & cmdReceived.text & "]"

    ElseIf (StrComp(str, "QL") = 0) Then
        cmdSent.text = "QL"
        WaitSeconds (0.3)
        sock_send.SendData "[" & cmdReceived.text & "]"

    ElseIf (InStr(str, "SETPOS") > 0) Then
        posAz = Mid$(str, 8, 5)
        posEl = Mid$(str, 14, 5)
        Call Position_ant(posAz, posEl)

    ElseIf (InStr(str, "AZ_SWEEP") > 0) Then
        startAz = Mid$(str, 10, 3)
        stopAz = Mid$(str, 14, 3)
        elevation = Mid$(str, 22, 3)
        stepAz = Mid$(str, 18, 3)
        intTimeAz = Mid$(str, 26, 3)
        directionAz = Mid$(str, 30, 1)
        Call Sweep_ant_az(startAz, stopAz, elevation, stepAz, intTimeAz, directionAz)

    ElseIf (InStr(str, "EL_SWEEP") > 0) Then
        startEl = Mid$(str, 10, 3)
        stopEl = Mid$(str, 14, 3)
        azimuth = Mid$(str, 21, 3)
        stepEl = Mid$(str, 18, 2)
        intTimeEl = Mid$(str, 25, 3)
        Call Sweep_ant_el(startEl, stopEl, azimuth, stepEl, intTimeEl)

     Else: sock_send.SendData "COMMAND ERROR"

    End If

End Sub

Private Sub Form_Unload(Cancel As Integer)
    sock_receive.Close
    cmdSent.text = "E" 'Close Accon
End Sub
```